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TRANSACTIONS

OF THE

Royal Geological Society

OF

CORNWALL;

INSTITUTED FEBRUARY 11th, 1814.

VOLUME THE SECOND.

"A knowledge of our subterranean wealth would be the means of furnishing greater opulence to the country, than the acquisition of the mines of Mexico and Peru."

President of the Board of Agriculture.

Penzance:

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1822.

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TO

THE MOST NOBLE

The Marquess of Hertford,

Lord Warden of the Stannaries of the Duchy of Cornwall,

AND

THE RIGHT HONOURABLE

The Lord de Dunstanville and Bassett,

Vice Patrons of the Society,

THIS

SECOND VOLUME OF TRANSACTIONS

IS MOST RESPECTFULLY

INSCRIBED.

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Geological Society

OF

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PREFACE.

FOUR years having elapsed since the Society published the first volume of their Transactions, the Council think it right to state that the delay of the second volume has not been occasioned by any deficiency of communications, but by a desire to render it more interesting to Geologists. They venture to hope that this intention has been accomplished by the selection of papers relating especially to the geology and mineralogy of Cornwall. On this account many valuable communications have been omitted, which, probably, would have made the volume more acceptable to the general reader.

A large space, comparatively, has been given to the detail of experiments on the temperature of mines; an enquiry rendered peculiarly interesting by the conflict of various opinions entertained on this subject. On one hand, the augmentation of heat in proportion to the increase of descent, has been combatted by strong and ingenious arguments; while, on the other, it has been maintained by deductions equally legitimate; and therefore the record of so many

facts, obtained by actual experiment, in circumstances favourable to the investigations, will, it is hoped, throw some light on this curious and much agitated question.

It was intended to have accompanied this volume with a geological map of the County; and it would not have been very difficult to delineate the surface in the manner usually adopted. Such a sketch, however, would not have fulfilled the wishes of the Society, which are to shew not only the varieties of rocks, but also the locality and position of the principal metalliferous veins, and the cross-courses which intersect them, as far as they can be ascertained. This work, so interesting to the geologist and to the miner, has already occupied much of the time and attention of some Members; but it is an undertaking of immense extent and labour; and the map of the lodes in one parish (St. Just) given in the present volume, will at once shew the nature and importance of the plan, as well as the time requisite for the completion of such an undertaking.

A considerable step has indeed been already made towards the attainment of this object, by the zeal and talents of a meritorious individual unconnected with this Society; and the Council

cannot allude to Mr. Thomas's Map of the principal mining district of Cornwall, without expressing their earnest wish that his work may obtain the patronage and encouragement it so well deserves; and also, their regret that all the mining districts have not yet been surveyed with equal ability.

Since the publication of the first volume, very many and valuable presents have been made both to the Library and the Museum, as are particularly specified in the list of donations, to which is subjoined the report of the Curator, which mentions the minerals of which the Cabinet is still destitute.

The Council have the pleasure of stating, that the mineralogical collection has, through the munificence of private individuals, become highly respectable; and being at all times open to public inspection, it has already excited a spirit of inquiry amongst the miners, which has led to the discovery of several minerals before unknown in Cornwall.

It is perhaps necessary to observe that the Society is not answerable for the correctness of either the facts or the opinions contained in the following papers: this responsibility rests solely with the respective authors.

ERRATA.

Page 65, line 7, for *blackish* read *bright*.
126, — 22, for *not from* read *not far from*.
127, — 24, 25, 26, for *and of Crennis, Huel Regent, and Huel Treasure copper mines*, read *and the east and west copper lodes in the neighbourhood of St. Austle*.
137, — 2, for *silicious* read *siliceous*.
161, — 18, for *above* read *below*.
169, — 26, for *winds* read *wins*.
172, — 11, for 216,000 read 432,000.
319, — 12, for *this mine* read *Botallack*.
322, — 17, for *vertical* read *longitudinal*.
329, — 21, for *are* read *were*.
338, — 5, for *at* read *as*.
339, — 8, } for *brakish* read *brackish*.
340, — 3, }
358, notes 3 and 4, for *Levant* read *Huel Spearn*.
363, first 2 notes, for *Isaiah* read *Ezekiel*.
385, line 15, for *Sulphuric* read *Sulphurous*.
400, — 20, for *and* read *used*.

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TRANSACTIONS.

I.—*On some Advantages which Cornwall possesses for the Study of Geology, and on the use which may be made of them.*

By JOHN HAWKINS, Esq. F.R.S., &c.

HONORARY MEMBER OF THE SOCIETY.

THE science of Geology, as far as it is founded on a close investigation of the nature of those stratified masses which compose the superior crust of the earth, and on the study of their relative age and position; appears to have taken its rise in Sweden and Germany about the middle of the last century. It acquired a great degree of popularity in the latter country, from the writings of Born and Ferber, and, soon afterwards, it excited the attention of philosophers in France and Italy.

The publication of the mineralogical Geography of Saxony by Charpentier, in the year

1778, may be said to have formed an epoch in the history of this science; for it was the first attempt, in the analytical way, to explain the geological structure of a great country. Many similar works, of less magnitude indeed, but on an enlarged scale of proportion, soon followed; and in the course of a few years Germany was inundated with geological essays relating to every part of that empire.

The language in which the earliest of these writers made known their observations and discoveries, was as vague and imperfect as might be expected from the novelty and originality of the pursuit in which they were engaged, but it soon acquired a great degree of scientific precision; and the observations which at first had been made in a manner too cursory and superficial, were gradually reduced to order, and assumed a better direction. The science owes this advantage to the school of Freyberg, which the genius of Werner soon rendered the central point of geological, as well as of mining instruction. In his lectures upon this subject, the earliest I believe that were ever given*, and which are strictly founded on the inductive process of reasoning, we have the first great outline of the method which nature seems to have pursued in forming the strata which compose the surface of the globe; and it is to his

* 1778.

unwearied zeal, his animating example, and luminous instruction, that we must chiefly ascribe the popularity which this science has acquired in every country of Europe.

The pre-eminence, however, which is so justly due to the school of Freyberg, has arisen in some measure from local circumstances; for it is situated in the midst of the deepest mines of Europe, and in a country (Germany) where mining operations have certainly been extended farther than we have any example of elsewhere. And here I must observe, that the advantages which any country has the reputation of possessing, for the study of geology, will bear in most cases an inverse proportion to its extent; the smallness of the space in which nature has exhibited the traces of her operations, rendering them so much the more obvious to our notice. Thus, for instance, a geological traveller may toil for weeks and months in his progress from the Rhine to the Vistula, without observing one fact worthy of record, if we except the blocks of syenite which are scattered over the surface of that sandy region; while the mineral mountains of Saxony, which occupy a space comparatively small, to the south of this line, will present to him most of the phenomena which illustrate the formation of the globe.

A country nearly of the same extent as that portion of Saxony, and scarcely inferior to it in

geological importance, is that which forms the immediate object of our attention. It presents, like Saxony, the traces of the earliest mineral depositions, and exhibits them in a still more striking point of view; while the facilities for observation are, upon the whole, much greater than they can be in any inland country. It is in Cornwall too, that the immense importance of its mining concerns has given to these pursuits an additional interest: the art of mining being in fact most intimately connected with a practical knowledge of the strata in which it is carried on. Accordingly, this sort of knowledge will be found to be very generally diffused among a certain class of our population, and to be made subservient to their speculations. In this limited sense, every miner may be said to be a geologist; and I have met with many of these, who, as far as their range of observation extended, had very correct notions of the leading phenomena.

Having already intimated what claims Cornwall possesses to be ranked among the primitive countries of the globe,—and these claims, as far as our patriotic feelings are concerned, will be readily admitted; I shall beg leave to consider how far the advantages arising from this distinction conduce to our instruction. With this view, it will first be necessary to remind my colleagues, that the primitive strata, notwith-

standing their very general diffusion, represent, in point of extent, but a small portion of the surface of the globe; that in the early period of their formation, nature appears to have acted with more uniformity and simplicity, than at subsequent periods; and that the absence of all organic remains in these masses deprives us of the means of tracing with sufficient precision, their relative antiquity. We have before us none of those compound stratifications, which exhibit the sudden and rapid changes of the fluid in which they have originated; and which bear such striking evidence of the revolutions to which they have since been subjected. We have none of that anomalous nature, which seem to connect the highest and the lowest members of the great series; or which exemplify the strong analogy between the Neptunian and the Vulcanic modes of formation. Even the gradations of the primitive class are here wanting; for we have no decided examples of gneiss, of granular marble, or of micaceous slate; which are so highly characteristic of it. Our school of geology, in fact, must be regarded as deficient in the materials towards a general and comprehensive system of instruction. What then, it may be asked, are the advantages which it really possesses? and what is the best use that can be made of them? The answer to this enquiry involves in it some considerations which

will oblige us to take a more enlarged view of the subject.

The strata which are so familiar to our observation in this remote corner of Europe, derive a particular interest from their ubiquity: they present the earliest results that we know, of the passage of matter from a fluid to a solid state; and in whatever situation they are found, they bear a striking appearance of uniformity: they belong in fact to that class which, being the most general, as well as the most undeviating in their composition and character, may be regarded as the most essential to the constitution of our globe. To illustrate this, it is sufficient for me to observe, that our granite and our argillaceous slate are found in every region of the earth, while the chalk which constitutes the basis of our midland counties, is confined to a mere spot on its periphery. On the other hand, the variations of most of the secondary rocks are infinite; and nothing can be more partial or capricious than their location: for the operations of nature, as we approach the termination of her labours, seem to have been more and more under the influence of local and transient causes; and the results, although they shew, in some instances, a renewal of her former efforts; bear too plainly, in most of these, the marks of her exhausted energy. The advantages therefore of a primitive country,

such as this is, in point of instruction, are of a very superior order; the phenomena all point to the earliest period that we can trace of the earth's formation; and they reflect some light, glimmering and imperfect as it is, on the circumstances which accompanied that great crisis.

It is easy to perceive that these circumstances must have varied considerably in regard to time, pressure, heat, motion, and fluidity; not only in the different rock-formations compared with each other, their component masses being in fact the result, some of a perfect, others of an imperfect or confused crystallization; but they must have varied to a certain degree in each of these masses individually; while the traces of what has been called a sedimentary deposition, are more or less observed in most of them.

To the circumstances already enumerated, which have had so great an influence on the crystallization of the great rock-masses of the primitive class, we may now add the varying proportions of the earths, which enter into their chemical composition. The number of these simple elements is but few, and of these, the siliceous, the aluminous, the calcareous, and the magnesian, constitute by far the largest portion: few, however, as they are, the variations resulting from the different proportions in which they are capable of combining, are numerous.

It is fortunate, perhaps, for the study of geology, that the actual forms of their chemical combination are very limited; while, on the other hand, the aggregation of these forms, in masses of great extent, is not much varied or multiplied. Under the first head we may enumerate quartz (which is a simple substance), carbonate of lime, felspar, mica, hornblende, talc, and chlorite, together with shorl, garnet, shiller-spar, and topaz, which may be considered merely as accessary. The different aggregations of all these natural species of the mineral system, with the sole exception of the carbonate of lime, have produced granite, gneiss, micaceous, talcous, chloritic, and hornblende slates, argillaceous slate, syenite, green-stone, and all the other rocks of the early trap-formation.

I have included our argillaceous slate in this arrangement of most of the aggregated and crystallized rocks, because there is much reason to consider it as an intimate mixture of quartz with mica, talc, chlorite, and perhaps in some instances with felspar. We may trace the last in those varieties of the slate which in this country are contiguous to the granite, and so well known under the denomination of killas: on the other hand, the talcous ingredient of the mixture is more conspicuous in the varieties which occur at a distance from the granite. This, however, I scarcely venture to advance

as a fixed opinion founded wholly on my own observations; but I submit it with all the deference that is due to those who may have better opportunities than I have had, either of verifying or of confuting it. It is certainly an object of no small importance to ascertain, if possible, the real nature of this rock: for, should the opinion which I have just hazarded be confirmed, the apparent anomaly in the disposition of the slate immediately over the granite will vanish; for the nature of the mixture in these two rocks, would be, in that case, not so different as to excite any surprize at their contiguity.

In noticing the marks of what has been called their sedimentary deposition, an allusion has been made to the stratification of the great rock-masses; and it is here, as in many other instances, that an ambiguous expression is borrowed for want of a better; by which means the progress of science is impeded by a reasoning built on false analogies. The meaning of sedimentary deposition ought, in fact, to be restricted to the arrangement of matter according to the specific gravity of its particles after a previous mechanical suspension; while the phenomena, which we call stratification, seem to be the result of some short but reiterated pauses in the progressive crystallization and consolidation of the great rock-masses.

In the instance which I have here given of the vague use of language, the cause evidently lies in the imperfect conception of the phenomena of nature: but the imperfection of language itself seems to have some influence, *vice versa*, in producing this confusion of ideas; which is undoubtedly the case in the vague manner of its application to those divisions of the rock-masses which determine the peculiar figure of their separated parts. Geology is an inductive science, founded on observation, and, in its present state, can no longer dispense with the ability to proclaim its progressive advancement. It is long since the attention of geologists has been drawn to the disposition observable in every distinct rock-mass, to separate in a form which is in some measure characteristic of its composition: although to this day, as far as I know, no general name has been given to this phenomenon. By some who have noticed a degree of uniformity in the angles resulting from the inclination of so many plane surfaces, it has been confounded with crystallization, and by others, on rather better grounds of reasoning, with stratification; although from the first it differs in the very material point of the structure of its mass, which is not one crystal, but an aggregation of crystals; and from the other, in that of continuity. It seems to be the effect of the contraction of matter at the period of its

consolidation, and is common both to the Vulcanic and the Neptunian formations; and this theory derives a further confirmation from the influence which the size and form of the aggregated parts of the mass have on the mode of its division.

I know no better generic name for this distinctive character, than that of Articulation, while most of its specific forms might be expressed by the terms prismatic, cuneiform, rhomboidal and tabular, of all which we are at no loss for examples in this county.

In stating to this society my thoughts on some of the modifications of matter which are observable in the oldest strata of the mineral kingdom, my object has been, first, to direct their attention to the causes which have had an immediate influence in producing the phenomena which pass under our daily observation; and, secondly, to establish a fixed language for communicating our ideas: the precision of these much depending upon the language with which they are associated. It is vain to expect this at an early period in the history of any natural science; but as the principal phenomena of this have now been well ascertained, and there is no want of zealous and active co-operation among the younger members of our society; it is to them that I more particularly address myself. They will perceive how cau-

tiously I have advanced any conjectures on the remote causes of what we see; and how little I value any theory which is founded upon an arbitrary arrangement of facts. Even the language of geology ought to partake of this neutrality, and by no means be strained to favour any particular opinions. Armed with the same caution, and possessed with all the ardour of youthful enthusiasm, let them enter the great field of observation which lies before them: their attention will soon be arrested by objects of the greatest interest, and the natural propensity of the human mind to classification and arrangement, which is perhaps the most pleasing exercise of judgment, will soon lead them to a closer investigation. Here the dawn of science commences. The field of enquiry may now be extended, and the facility with which this may be done in the direction of the sea-coast, affords every stimulus to youthful exertion. I shall conclude with a reflection, which will not be thought irrelevant to the subject of this communication.

The study of the little planet which we inhabit, together with all the varied forms of animal and vegetable matter which adorn it, appears to be one of the most rational employments of man during his short existence. There is no purer source of intellectual pleasure, and scarcely any thing which raises our conceptions so much

of the Almighty Creator. Yet how heedless of these objects, except as they minister to our use, do we pass through life, in spite of all the curiosity which is implanted in us by nature. The crystallized matter upon which we tread, and even those useful minerals which we extract with so much avidity from the bowels of the earth, scarcely excite a desire in most of us to know how they were formed, or in what relation they stand to the rest of the creation. In an age so enlightened, this insensibility is opprobrious to us, and will no longer be tolerated. An appeal has already been made to our latent energies, and I confidently hope that the institution of this society will lead us back to that neglected study, which so powerfully attracted us when young; and from which, neither the amusements of the fashionable world, our professional pursuits, or the heat of political contention, have weaned us entirely when old.

II.—*On the Temperature of Mines.*

By ROBERT W. FOX, Esq.

MEMBER OF THE SOCIETY.

(Read September, 1819.)

I believe most persons acquainted with mines are aware that a great degree of warmth is experienced at considerable depths under the surface; but this fact does not appear to have attracted so much notice as it probably deserves.

My attention having been called to this subject in 1815, I instituted enquiries, and caused some experiments to be made, in the mines of Huel Abraham, Dolcoath, Cook's Kitchen, Tincroft, and in the United Mines. The information I have thus acquired, I have endeavoured to communicate in the accompanying scale, (see Plate I.), which exhibits at one view, the results which have been obtained in each of those mines.

The temperature in Cook's Kitchen and Tincroft, it may be remarked, was inferior to that in the other mines at corresponding depths;

owing, I presume, to the bottom levels of the two former having been for a considerable time filled with water, accumulated, without doubt, partly from above; by which means, the temperature, not only of the water, but also of the air, in these mines, must have been affected. In the United Mines also, there was some water when the observations were made; but it remained too short a time, I apprehend, materially to affect the general temperature of the mine. Dolcoath and Huel Abraham were clear of water to the bottom; and it will be observed that the temperature in the corresponding levels of these mines differed very little, and, with a few trifling exceptions (which probably arose from local causes), the heat progressively increased, even to the greatest depths to which they have been hitherto explored.

A few months ago, I requested a friend of mine to try similar experiments in some collieries; but I have not yet received his report. I was, however, pleased to find by the Cornwall Gazette of the 4th September, 1819, that observations have been made on the temperature at the bottom of some of the collieries in the north of England, and that the only two results therein stated agree very nearly with those obtained at corresponding depths in our mines. In one colliery, at the depth of 882 feet, or 147 fathoms, the temperature was found to be

68°, whereas at the surface it was 19° less; and in another, at 1200 feet, or 200 fathoms beneath the surface, the mercury rose to 74°, which was 25° higher than at the surface. Hence it appears that the increase of temperature at considerable depths in the earth is not peculiar to our mines.

Without entering into speculation on the exciting cause, or the extent of the internal heat, it is probable that the ascent of warm vapour may produce the high temperature noticed in mines; and that its effect is more or less considerable, in proportion to the facility with which it finds a passage upwards. This is rather corroborated by the fact, that water flowing from large metallic veins is generally the most remarkable for warmth.

It appears from experiment, that the quantity of caloric in a sensible and latent state, as well as the quantity of water, increases in vapour or steam, (if in contact with water,) nearly in proportion to the augmentation of its elasticity.

On these properties of vapour, and its copious supply from the interior of the earth, many important operations of nature seem to depend. It is presumed that its effect is to modify the extremes of heat and cold, both in the earth and the air. In winter, its ascent and condensation, as it approaches the surface, probably tend, in a considerable degree, to equalise

the temperature of the soil, and to protect the roots of plants from frost.—It seems also to account for the dampness which may always be observed on the surface of the ground, after the breaking up of a hard frost, however dry it may have previously been.

In summer it may be supposed to keep up the supply of moisture as evaporation proceeds, thus mitigating the influence of solar heat, which might otherwise dry up the soil, and prove injurious to vegetation.*

It may also contribute to the formation, and supply, of springs of water; and rain, independently of its direct effect, as well as cold weather, may augment them, by promoting the condensation of the vapour in the earth.

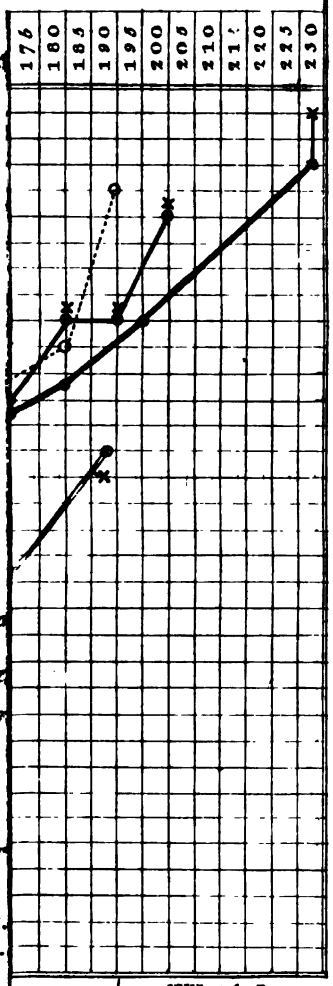
It is difficult to suppose that the moisture derived from the atmosphere, after making a reasonable allowance for the water which flows over the surface into the sea, is, *even in this climate,* at all adequate to the supply of the copious evaporation from the earth's surface. It is not easy to make satisfactory experiments on this subject, but it appears, that such as have been made on insulated portions of earth, should not be considered conclusive.

* Does not this partly explain the reason why clayey and stiff soils are colder than those of a looser nature?

I cannot conclude without expressing a hope, that the subject of internal heat may attract more general attention, and that as many facts as possible relating to it, may be accumulated from various and distant places.

were taken.

Min



J.P. Vibert. Sc. Penzance.

T DEPTHS.

Remarks.

The round marks show the temperature of the air. The X marks that of the water.

The points marked S L. show the depth in the respective mines, which correspond with the level of the sea, as stated in Rich.d Thomas's survey.

Dolcoath, Cookskitchen, & Tincroft, are in argillaceous schistus and Granite, the latter bar ground the former.

The United Mines are in argillaceous schistus, containing large masses of Porphyry.

The temperature having been ascertained in Wh: Abraham at two different periods of the year, the result of both periods is given.

III.—*On the Temperature of Mines.*

By ROBERT W. FOX, Esq.

MEMBER OF THE SOCIETY.

(Read October, 1820.)

I had the pleasure to communicate, at the last annual meeting, the result of some observations on the temperature of a few of the mines of this county; from which it appears, that there is a progressive increase of temperature, in descending from the surface to the greatest depths hitherto examined. I now beg to submit the result of some further enquiries upon the same subject.*

The table which accompanies this paper, contains a general view of the heat observed in, or near, the metallic veins, in different mines. I had

* I have been greatly assisted in these enquiries by Capt. Thomas Lean, of Huel Abraham, John Rule, Jun. of Dolcoath, Capt. William Teague, of Treskerby, Michael Williams, Jun. and Capt. Richard Hosken, of the United Mines, and Capt. Williams, of Huel Vor. I must also express my obligation to my friend Joel Lean, of Frenchhay, near Bristol, who first drew my attention to this interesting subject.

made a second table, containing the results of several experiments on the temperature of cross levels, and shafts, in some of the same mines, at a distance from any metallic veins; but as its contents are too various, and extensive, to be comprised in a printed sheet, I will merely mention a few of the particulars.

In Dolcoath, at the depth of 130 fathoms, where the temperature of the earth, in the vein, was 63°; its temperature in a cross level, at the distance of 60 fathoms from the vein, was 62°.

In the United Mines, at the depth of 160 fathoms, the temperature of the earth, in the vein, was 75°; but in a cross level, south of the vein, only 69°.

In the same mines, the temperature of the water, in the vein, at 140 fathoms deep, was 67°; and that of the earth, nine fathoms north of the vein, was exactly the same.

In Ting-tang, at 80 fathoms deep, the temperature of the earth, in the vein, was 64°; and at the depth of 110 fathoms, it was 68°; whilst in a cross level, 90 fathoms deep, and 30 fathoms distant from the vein, it was 64°.

In Huel Squire, at the depth of 110 fathoms, the temperature of the air, near the vein, was 72°; but in a cross level, at some distance, it was 69°.

In Treskerby, at 120 fathoms deep, the temperature of the air, near the vein, was 72°; but at some distance, in a cross level, 66°.

In Chacewater, the temperature of the earth in the vein, at 100 fathoms deep, was 82°; and that of the air, at some distance north of it, 79°.

These instances, which are selected from a great number, the result of which is very similar, will suffice to shew that the temperature, at a distance from the metallic veins, and at the same depths, is, on an average, nearly three degrees below that of the veins, as given in the printed table.

In many of the observations referred to in the tables, the bulb of the thermometer was buried in the veins, or rock, to the depth of at least six or eight inches, and was filled round with earth, &c., so as to prevent the free admission of air.

If we take the mean temperature of the surface of the earth in this latitude, at 53°, as given in Professor Mayer's Tables; the mean of the accompanying table shows an increase of a little more than 6° of Fahrenheit, for every 50 fathoms, or 300 feet, in depth. As my second table gave a less ratio, perhaps we shall not much err, if we suppose an augmentation of one degree of heat, for every ten or twelve fathoms in depth, at least in this part of our island. It is however difficult to determine satisfactorily the true ratio of the increase of temperature, as it is evident that there exist many local and accidental causes, which operate in our mines,

and affect their temperature. The lighted candles, and the blasting of the rocks, have doubtless some influence in augmenting the heat; and the presence of the workmen must also have the same tendency, although probably in a small degree at the bottom of deep mines, where the temperature so nearly approaches to that of the human body;—moreover, the warm vapour, and air, which always arise from the bottom of mines, must raise the temperature of the upper levels in a greater or less degree, according to their relative situations. On the other hand, the currents of air which descend through some of the shafts, or are forced through the air-pipes for the supply of the miners, and likewise the water which finds its way through the strata, and veins, from more elevated situations, doubtless tend, in a considerable degree, to diminish the heat in the deeper levels.

How far these opposite causes may counterbalance each other, it is not easy to ascertain; but if duly considered, they will greatly reconcile the want of complete accordance in the results noted in the tables: and it is evident, that observations made on the temperature at the *bottom* of mines, are most to be confided in, not only for the foregoing reasons, but also because of the proximity of this part to the unbroken ground. There are some cases in which it cannot be supposed that the high

temperature observed can be occasioned by any accidental circumstance. At the bottom of Dolcoath mine, for instance, there is a large stream of water issuing from one of the veins at 82° of Fahrenheit, while the air near the same place is generally one or two degrees lower:—this is only one example amongst many of the same kind. The most striking one I have heard of, was reported to me by Capt. Hosken:—An accident having happened to a steam engine at the United Mines, the water increased so much as to fill the levels marked in the table 190, and 200 fathoms, under the surface; and thus it continued for two days. Immediately after it had been pumped out, and before the miners had begun to work in those levels, he ascertained the temperature of the ground in the upper one to be 87½°, and in the lower one to be 88°. On renewing his observations some days after the men had resumed their work in these places, the heat had rather diminished than otherwise.

It is worthy of notice, that the principal part of the work is not always carried on in the deepest part of the mines: on the contrary, there are often more workmen employed at twenty or thirty fathoms above the lowest part, than in the deepest level. If therefore the increase in the temperature were wholly the effect of adventitious causes, that increase would be

greatest where those causes had their largest operation: but the facts which I have detailed in the table, prove that, however various may be the operation of accidental circumstances, in different parts of the mines, the temperature invariably increases with the depth.

My friend and relative, Joseph T. Price, of Neath, Glamorganshire, has furnished me with the results of some observations made last spring, in three collieries in the neighbourhood of that place. The thermometer was buried for many hours, from one to two feet under the ground, at the bottom of each of these collieries: in one of them, which was only 10 fathoms deep, the mercury stood at 50°; in another, 36 fathoms deep, it stood at 58°; and in the third, which was 90 fathoms deep, it stood at 62°. The difference between the first and last mentioned collieries, was 12°, which ratio nearly corresponds with that obtained in our mines.

It has been surmised that the heat noticed in the mines may be attributed to the presence of metallic, and other inflammable substances; but when all the facts are considered, no causes, merely local, can be imagined capable of producing such constant, extensive, and powerful effects. If the water received its heat from the metallic veins, while passing through them, it would surely become strongly impregnated with mineral substances;—this is not, however, the

case. I analysed some from the deepest part of Dolcoath, taken at 82°, immediately from the copper vein, and obtained from a quarter of a pint of it, only half a grain of residuum, consisting of sulphuric acid, some oxyd of iron, and a little lime. I found a greater proportion of the same substances in some water from a cross level, at a distance from any vein, 200 fathoms deep, in the same mine.

Water from the bottom of the United Mines, of the temperature of 82°, contained six grains of muriate of lime in a quarter of a pint. Some water taken from the deepest parts of Treskerby and Ting-tang, was, from the former mine, very slightly impregnated with sulphate of iron, and had a trace of muriatic acid; and that from the latter mine contained a very minute portion of the muriate of lime.

It is satisfactory to find, that the experiments which have hitherto been made in collieries in the north of England, and in some mines in Saxony and Switzerland, confirm the fact, that the temperature of the earth increases at considerable depths. I have not yet met with the statements which have been published detailing this information. The paper relative to the temperature of the latter mines, I apprehend has appeared in a number of the "Annales de Chimie et de Physique," published at Paris early in the present year.

So general and interesting a coincidence, at places so distantly separated, strengthens the belief, that the heat hitherto observed in the deepest excavations, has one common source in the bowels of the earth; and that the internal temperature, and the circulation of vapour and water, at and under the surface, are intimately connected with, and, in a great degree, dependent on, each other. In my last communication, I alluded to this interesting part of the subject; I therefore shall not enlarge upon it at present; but I may just add, in confirmation of what I have therein suggested, that from the experiments I have made, it appears that vapour arises from the surface of the earth at all seasons of the year, and by night, as well as by day*: even during a severe frost, after removing the frozen surface of the ground, it has condensed within

* Having alluded to the evaporation of moisture from the earth's surface, I wish just to add, that I conceive it helps to explain the cause why more rain falls on low, than on elevated ground. Every shower of rain must condense more or less of the ascending vapour, in proportion to their relative temperature, and the distance the rain may fall through it; and for these reasons, and the superior temperature of vallies, the quantity of rain is necessarily greater in low, than in high situations. Hence I presume that rain gauges placed at different elevations, will differ most in warm showery weather, and least of all in rain of long duration.

I am induced to make these remarks in consequence of having observed communications on the subject of rain gauges in several of the recent numbers of "Thomson's Annals of Philosophy," in which their want of agreement at different elevations, is attributed to local and accidental circumstances, without any reference to the condensation of the moisture contained in the atmosphere.

an inverted receiver. The sun, I am aware, is a powerful agent in producing evaporation; but I cannot discard the idea, that the internal heat has also a share in this very curious and important part of the economy of nature.

Additional Communication, read October, 1821.

SINCE my last communication on the subject of the temperature of mines, I have had a thermometer, four feet long, placed in a hole three feet deep, in a copper vein, at the end of the deepest level, or gallery, in Dolcoath, which is 230 fathoms, or 1380 feet, under the surface: a spot where no workmen were employed, and where the current of air must have been small. The hole was filled with clay round the stem of the thermometer, so as to prevent the circulation of air near the bulb, and in this situation it remained more than eight months. It was often examined during that period, and was always found to indicate a temperature of 75°, or 75½°, unless it had been recently overflowed by water. This happened several times, in consequence of accidents to the machinery of the mine, and more than once, the water filled the level for

some weeks. As soon as it had subsided, so as to permit access to the thermometer, the quicksilver was observed to have risen to 77°, but in two or three days it again fell to $75\frac{1}{2}$°.

n or near the vein

Dep in Fathe	hasewater n & Copper ept 1820.	Huel Unity Tin vein Aug. 1820.	Huel Vor Tin vein Nov. 1819
1t			S. w. 52°
10.			
20.			S. w. 61°
30.	S. a. 61°		
40.			
50.			
60.		S. a. 66°	
70.	S. a. 70°		
80.	S. a. 78°	S. e. 66°	S. w. 63°
90.	S. e. 82°		
100.			S. w. 64°
110.			S. w. 66°
120.			S. w. 70°
130.			S. w. 69° a. 72°
140.			
150.			
160.			
170.			
180.			
190.			
200.			
210.			
220.			
230.			

S. *Shist*. P. *Porphyry*.

or water.

IV.—*On the stratified deposits of Tin-stone, called Tin-floors, and on the diffusion of Tin-stone through the mass of some primitive rocks.*

By JOHN HAWKINS, Esq. F.R.S., &c.

HONORARY MEMBER OF THE SOCIETY.

When we consider how large a portion of the metallick capital of Europe is the produce of mineral veins, it is by no means surprising that these should have occupied, almost exclusively, the attention of our miners. This is particularly the case with tin, the veins of which are so rich and so numerous in this county, that, with the exception of the alluvial beds of this metal, in our stream-works, every other mode of its deposition in the bowels of the earth, seems to have been overlooked or disregarded.

I am inclined to think that the direction which has thus been given to the spirit of mining enterprize, is both unfavourable to science, and in a very material degree prejudicial to our interests: for notwithstanding the

greater concentration of metallick produce in our lodes, and the advantages which arise from its more rapid extraction, and easy preparation; I much doubt whether the profits to the immediate adventurer are, upon the whole, so much larger as to justify this preference.

To ascertain what these profits are, in particular cases, may be of some use for our local guidance; but the more important question which I would here propose, is, what is the rate of interest on the whole capital which is risked in exploring our tin-lodes, deducting the premium of insurance on that risk? A fair estimate of the expenditure and the return from all the tin mines that have been working for the last twenty or thirty years, if the necessary documents could be obtained from those who are interested in withholding them, would dispel the great delusion which prevails on this subject, as well as check that ruinous spirit of gambling adventure, which has been productive of so much misery. Perhaps it would then appear that the same interest of capital, or even a greater, might be obtained, with infinitely less fluctuation in its amount, from situations where nature has scattered her favours with a more sparing hand, but in a more equal manner: I allude to those mineral deposits, which our miners call tin-floors, and more particularly to those important objects of mining industry,

which the Saxons call stock-works, should they be found to exist here.

It is with a view to this very desirable change in the current of our mining opinions, that I lay before the society some information on both these subjects, which may be the means of opening a new field of enquiry both to geologists and miners. Of this, a part has been extracted from my own journals, and the rest, in an abridged form, from the printed reports of very accurate observers.

With respect to the first mentioned class of mineral deposits, it is not in my power to point out many decided examples in this county; some are said to occur at Bal-an-uûn in the parish of Lelant, and at Huel-grouan in the parish of Breage; and, if I am rightly informed, Curclaze mine, near St. Austle, belongs to this class, and merits a very particular examination.

I shall beg leave to direct the attention of this society, in the first place, to those floors which I have myself examined on the sea cliffs of the parish of St. Just. A belt of iron-stone (here called killas), which is scarcely more than one hundred fathoms in breadth, skirts along this coast, on the edge of the grouan. This rock breaks in a rhomboidal, rather slaty form, and the beds dip in an angle of from 15° to 20° to the north-west, and to north by west; that is, from Botallack northwards, they dip towards

the sea, and rise towards the grouan. The lodes which traverse this rock are even more full of iron than those in the grouan, and it is remarkable, that they all carry copper, with a little tin; while those in the grouan bear tin only.

I was particularly struck with the phenomena which presented themselves at Roscommon cliff. This spot is distant about 100 fathoms northward from the tail of Botallack adit. The several lodes of Botallack unite here, where they attain a breadth of several fathoms; but as the back of this complex lode has been worn away by the tide, the hollow interval has nearly severed this rocky promontory from the main land, and rendered it a peninsula, in extent about one fourth of an acre, the opposite cliff towering to a great height above it.

The strata here dip north by east in an angle which varies from 15° to 20°. They are composed of alternate beds of garnet *(en masse)*, and hornblende-slate (a variety of our ironstone), the former being partly granular, and partly compact, containing here and there a few spots and joints of large grained cockle (shorl). A lode of the same granular garnet, without walls, one foot wide, runs through the centre of this rock, bearing north-east and south-west. A vein of quartz (very ochreous), one inch wide, runs nearly in the same direction. On each side

of this vein there is a fine seam of blue efflorescent oxyd of copper. On the eastern side, the hornblende slate is slightly impregnated, to the breadth of two or three inches, with white cobalt-ochre, the joints of the rock being frequently filled with cobalt-bloom.

The whole tenement of Botallack is said to be full of tin-floors. Grylls's bunny is a name given to one of these, or rather to a number of small floors alternating with an ochraceous iron-stone, to the depth of ten fathoms. These floors dip three feet in a fathom to the north, and have been worked about forty fathoms on their underlie, and as many on their line of bearing. The general produce is 150 *lbs.* of white tin in 100 sacks.

Near these I observed some floors of cockle, varying in breadth, and alternating with the iron-stone, tin being generally found beneath them. These underlie likewise to the north. I believe I am the first person who has detected in these floors the presence of that rare substance, the axinite.

Mineral beds, which we call floors, are not unfrequent on the highest ridge of the mountains which constitute the boundary line between Saxony and Bohemia. Those at Zinnwald have long been the object of mining adventure, and are still worked with profit. They are on the Bohemian side of the ridge, and on

one of its highest points. The strata here consist of a fine grained, half decomposed granite, which alternates with the tin-floors. These again consist of quartz, mica, and gneiss, or, to speak with more precision, each floor is again divided into the following subordinate beds; first quartz, secondly mica, thirdly greiss-stone, or a rock composed of quartz and mica in a peculiar state of aggregation. The tin is found interspersed in the second and third of these beds, together with fluor-spar and wolfram.

Some of these floors have a considerable inclination to the horizon, but they are said to be of little extent, so that it is feared that the workings will not be of much longer duration. The whole mountain containing these floors, is intersected by a number of small fissures, and regular lodes, which are seldom metalliferous, and always occasion a partial subsidence of the strata; but the laws of these disturbances are so well understood by the miners, that they rarely fail to discover the lost segment again.

Similar floors, composed of magnetical ironstone, tin-stone, and pyrites, occur in other parts of the same range of mountains. That situated at Breitenbrunn is one of the most considerable of these, and although it has been an object of mining enterprize for several centuries, it is not yet exhausted. This floor, which has been worked to an extent of about 600

fathoms, lies in a sort of gneiss rock which shews a transition into micaceous slate. The average of its underlie is about 25° to the south-west. Its bigness, which varies from $\frac{3}{8}$ to 4 fathoms, is usually $\frac{3}{4}$ of a fathom, and the principal shafts are sunk through it, to the depth of 20 fathoms below the surface.

This mineral deposit may properly be divided into two parts, the bed or floor, and the *kamm*, as it is here called, or overlier. The latter consists of a more or less distinct aggregate of chert, quartz, hornblende, chlorite and actinolite. Some portions of the mass have the appearance of a reddish grey striped chert, which may arise from a finer and more intimate combination of the quartz with the felspar; others resemble hornblende-slate, and others a very hard hornblende-rock of a greenish colour; all these constitute a mass so firm and hard, that the working of a fathom usually costs from 50 to 60 rix dollars.

The transition of the overlier into the floor is very gradual. The latter contains iron ore both magnetical and specular, all the various sorts of pyrites, blende, tin-stone, red iron-stone, garnet, actinolite, chlorite, indurated clay, hornblende, fluor-spar, and occasionally quartz, calcareous-spar and apatite. The pyritous contents of the floor lie immediately beneath the tin-stone, and abound most in the deepest parts of

the mine, which is now principally worked on their account. A part of the floor and its overlier is intersected by lodes of silver ore, of little importance, except in a geological point of view. The intersections are accompanied with a subsidence on the hanging side of the lodes, extending from one to four fathoms.

The above examples of tin-floors in Cornwall and on the continent, may all be referred to the same class of geological phenomena. I suspect, however, that this denomination has been applied in some instances to deposits of a very different description, which bear some remote analogy to floors. How far this has been the case at Trewidden Bal, in the parish of Madron, will appear from a consideration of the following particulars.

The country, (to use the language of our miners,) in which this mine is situated, consists of alternate beds of killas and elvan, in the latter of which is found the tin. These beds dip to the E. N. E. and somewhat quicker than the fall of the hill towards Trereife. The tin-floors, as they are here called, follow the inclination of the strata. Correctly speaking, they are small, very short fissures or veins, which run partially through the elvan, varying in breadth from half an inch to eight or nine inches, and so irregular and interrupted as to render it difficult to ascertain either their direction or their un-

derlie. These small capricious veins appear frequently to diverge from a central body, and then bear some resemblance in form to the spreading roots of a tree. The tin-stone is found here and there in very large and solid masses; in general it is more or less mixed with quartz, and sometimes, although rarely, with cockle (schorl en masse). It is precisely that variety of tin-stone which is found at Roche and St. Denis, being distinguished by its columnar crystallization. Its specific gravity and metallic contents are less than that of any other.

In another part of my journal I find some farther particulars of this singular mine.

The floors underlie four feet in six to the north-east. There are several of these, and each of them occurs in a white porphyritical rock, which varies in thickness from two to three feet, and alternates with beds of killas, the thickness of which is three feet or thereabouts.

The white porphyritical beds, called here the tin-mother, appear, as they descend, to get nearer in some places, to each other, and the beds of killas to grow thinner. The latter are even sometimes wedged off by the junction of two beds of the white stone. Hence, great hopes are formed that this stone will soon be

found in a compact body, and the numerous floors of tin concentrating in it.

The first floor occurs at the depth of three fathoms from the surface, but the old works in the coffin are evidently on floors, which lie much deeper than those which are at present explored here. Several lodes intersect these floors. One of these, called Tangy course, composed of quartz, and varying from one fourth of an inch to eight inches in bigness, runs in a north-westerly and south-easterly direction, crossing the tin-floors and enriching them. Another course runs in the direction of the longest diameter of the coffin, or about north by west, and is of the same breadth and nature as the Tangy. Some more small courses of quartz run through the floors, and usually enrich them. Two of these, called the orchard courses, run nearly east and west. There are moreover a few small veins of cockle, which cut through the tin-floors, and underlie south about three feet in a fathom.

As the adit here is at a very shallow level, and no great mechanical powers have ever been applied to the working of this mine, the excavations are extremely irregular, and it is probable that much of the tin is still left untouched in the old workings. In a mine so conducted, it is extremely difficult to ascertain all the circumstances which characterize this singular

deposit, but those which I have described will shorten the labour of some future investigator. In the vale below, to the southward, have been found some very curious specimens of wood-tin.

Every mode in which tin is found deposited by nature in the strata of the earth, must be an interesting object of enquiry to a Cornishman. I need no apology therefore for introducing here some account of those remarkable tin mines which are so well known in Saxony under the name of Stockworks. The following literal extract from my journals relates to the largest and most interesting of these.

"At Alt Frauendorf, on our road from Dresden, occurred the large grained porphyry, or that variety which shews the transition from the porphyritical greenstone of Werner into the common porphyry. This rock continued all the way to Altenberg.

Altenberg lies on one of the highest points, or, as it may be said, on the very crest of the Erzgebirge, (mineral mountains). The Geyersberg, which is, properly speaking, the same mountain as that on which Altenberg is situated, rears itself at the distance of a few hundred yards from the town into a lofty cone, which appears to be entirely composed of basalt.

The famous Stockwork (a stumbling block in the way of geologists) is nothing else than a large mass of the mountain impregnated with

tin-stone, occasioned by the meeting of a number of lodes and veins at this point, some of these crossing each other nearly at right angles, some bearing each other along in their crossing, and others stretching along in a parallel or nearly parallel direction. The same natural cause seems to have produced, at the same period, an infinite number of smaller veins and fissures, which run in all directions through the rock, so that many parts of the Stockwork bear a striking resemblance, on a larger scale, to the veined varieties of common marble.

The veins here are chiefly of quartz, and are united to the rock in such a manner as to indicate their coeval formation. It is remarkable, however, that the tin lies for the most part dispersed through the latter, and this circumstance has given occasion to the very singular mode of working the mine; for as no profit attended the driving upon regular lodes, and the mass of rock was unequally impregnated with tin, the greatest degree of irregularity appears to have marked the progress of the excavations from their commencement. This defect in the plan of the work has been carried to the most pernicious excess, first by the number of different sets of adventurers which were formerly crowded together in this small spot; secondly, by the little regard each of these had to their own future advantage, or to the common interest; and

lastly, by the want of a proper controul on the part of the mining administration at Freyberg. The immense excavations, therefore, and the little attention paid to the support of the rock above, brought on the fatal catastrophe of the year 1611, when the whole extent of country which had been undermined, including an area of some acres on the side of the mountain, sunk in at once to the depth of 100 feet, and involved a considerable part of the entire rock in the ruin.

The present works are carried on partly in the accumulated rubbish of the old, but chiefly in the entire rock beneath it, and in the following manner: wherever the rock is sufficiently rich in tin, and too solid to be broken with the hammer and iron, which is generally the case, an opening is made by wood-firing, and this opening is extended either in length, breadth, height, or depth, wherever the rock is sufficiently productive to answer the costs. The arched form which has been given to these excavations, added to the natural solidity and cohesion of the rock, enables the miners to carry on these to a prodigious extent. The capacity of one of them, called the Christopher opening, is equal to that of the inside of a cathedral. The total want of regularity, however, in the plan of the works, as they have hitherto been conducted, very little attention having been

paid to the preservation of levels or platforms, which are so essential to their strength and durability, will, it is apprehended, at no distant period, cause a recurrence of the former catastrophe.

The rock itself, which composes the Stockwork, is a variety of porphyry, the mass being a fine mixture of chlorite earth and clay, in which the grains of felspar and quartz are scarcely perceptible. The colour of the whole is a greenish grey, but the faces of the joints are covered with iron-ochre.

Molybdena occurs here in a quartz lode, and now and then are found bismuth, specular iron ore, wolfram, white and yellow mundic, steatite and topaz. Pihnit and mica belong likewise to this formation, and the two latter compose a bed or floor.

The tiefer stollen, or deep adit, is driven from the vale below Alt Geisig, first, through micaceous slate; secondly, through porphyry; and thirdly, through a course of small-grained half-decomposed granite, into the variety of porphyry above described. The levels in the Newfanger mining district, situated between the Stockwork and Geysingsberg, are driven upon several contiguous and nearly parallel lodes, which stretch in a direct line towards the Stockwork. These lodes are rich in tin. The annual produce of this object of mining indus-

try, is, on an average, about 1400 centner or Saxon cwt. of metal. The works are now carried on by two sets of adventurers, and on a more enlarged and better regulated plan."

In the account which is given of this Stockwork, by the author of the mineralogical description of Saxony, I find that it has been worked nearly four centuries. The vertical depth from the original surface of the ground to the untouched rock, is nearly 300 feet. The present workings are sunk beneath this, to the farther depth of 330 feet.

The Stockwork at Geyer, in Saxony, is another remarkable instance of the capriciousness of nature in the distribution of her mineral treasures. The following particulars of it are extracted, in an abridged form, from a very able report on the state of the mine, drawn up by Mr. Telpe, the director.

This celebrated Stockwork was first worked at the close of the fourteenth century, as an open quarry. The rock in which all the mining operations are here carried on, consists of granite, which is overlaid and surrounded by gneiss: its form is conical, but compressed, its longest diameter bearing north and south.

The summit of this granitical rock is supposed to have originally projected above the surrounding gneiss, and to have an uninterrupted communication beneath it, with a group

of granitical craggs or torrs, which, at the distance of about two miles and half to the north, project from 30 to 100 feet above the gniess, The whole rock is now worked out to the depth of from 10 to 30 fathoms below the surface of the surrounding country, and has the appearance of an immense quarry, varying in its length from 100 to 110 fathoms, and in breadth from 70 to 80. Its constituent mass is a fine-grained reddish-white hard granite, in which the felspar is by far the most abundant ingredient. It lies in beds from $\frac{1}{4}$ to 3 fathoms in thickness, dipping in an angle of from 5 to 10 degrees towards the south-east; and divided by clefts or fissures which cross each other in all directions, both in their bearing and in their underlie. The surrounding gneiss, on the other hand, dips from 5 to 15 degrees towards the north-west, and is intersected in the same manner with clefts or short fissures, which are inclined more or less towards each other. The granite, however, is not in immediate contact with the gneiss, being covered or surrounded by a shell which is from $\frac{1}{8}$ to $1\frac{1}{2}$ fathom in thickness, and is here called the Stock-scheider or divider. This is likewise of granite, differing from the other in the less equal dispersion of the three constituent parts of the mass, and in the larger size of the felspar crystals.

The whole of this mass of rock is intersected by an inconceivable number of parallel, but irregular veins of tin-stone, varying from $\frac{1}{4}$ to 4 inches in bigness, and in the vicinity of these veins it is impregnated with tin-stone. These small veins, which are firmly united to the contiguous rock, and are of contemporaneous formation, approach each other often and come into contact, and are as often borne away in their course and underlie, to the right or left. Sometimes they are wholly cut off, but reappear in their former attitude and direction, after a short interval; and, generally speaking, they continue their course, under these circumstances of occasional interruption, from one end of the stockwork to the other, terminating nevertheless, without exception, in the line which bounds it.

Through the middle of this veiniferous mass of granite, runs a large lode from $\frac{1}{4}$ to two fathoms in bigness, the direction of which makes an angle of from 35° to 40° with the former. It underlies, as they do, from 60° to 80° southward, and continues its course through the gneiss. This lode has regular walls, intersects many of the veins, contains no tin, and is filled, where it runs through the gneiss, with quartz, ochreous clay and decomposed gneiss, and where it traverses the granite, it contains, together with the same clay and quartz, red chert and decomposed granite.

mediate adoption of the Saxon process of stamping and dressing. No man who has witnessed this process, can forbear reprobating our own, as rude, wasteful, and inefficient; for if, with any truth, it may be said that in the art of mining we are inferior to our continental neighbours, we are so in a most shameful degree in the department which I have just mentioned.

V.—*On the relative Age of the Veins of Cornwall.*

By JOSEPH CARNE, Esq. F.R.S., M.R.I.A.,
Hon. M.G.S.,

MEMBER OF THE SOCIETY.

(Read October, 1818.)

Although there is, perhaps, in no part of the world, a district of equal size, which can compare with Cornwall in the number and variety of its mineral veins, and the geological phenomena which attend them; most of the writers on this part of geology have, 'till lately, drawn their facts and illustrations from foreign countries. This is not at all surprizing; for it is but a few years since Britain has been roused to the pursuit of this science; and still fewer since Cornwall has attracted that degree of attention, either from strangers or from its own inhabitants, which is now so generally paid to it. Perhaps, however, few circumstances have occurred in relation to mineral veins,

either in Hungary, Saxony, or Bohemia, which may not be observed in the veins of our own country.

The original formation of veins is a subject on which the two great parties which now compose the geological world, are almost as distant from each other as the surface of the earth is from its centre. It is, however, unnecessary to enter into their controversy at present. Circumstances relating to the Cornish veins will probably be adduced in the course of this paper, which may appear to favour the theory of each party. The singular situation, connexion, and appearance of the granite veins at St. Michael's Mount, and in some other parts of Cornwall, have been considered by the Huttonians as decisive proofs of the truth of their system: whilst the pebbles, or rounded fragments, in the metalliferous vein of the Relistian mine, have been regarded by the opposite party as unaccountable, on any other principles than those of the Wernerian theory.

The diversity of sentiment which exists with respect to the mode in which veins were originally formed, may possibly lead to a difference of opinion as to their positive age, or to the period or periods of their actual formation: but with regard to their comparative or relative age, I apprehend all parties (except those who hold that all veins are contemporaneous, and were formed

at the same time as the containing rocks), are agreed on this important principle: *that a vein which is intersected, or traversed, by another vein, is older than the vein by which it is traversed.* This principle is slightly alluded to by Borlase, who quotes Hutchinson's authority for it:* but Pryce was, I believe, the first who plainly laid it down, in his Mineralogia Cornubiensis.† It is the principle on which Werner lays the greatest stress, in his New Theory of the formation of Veins:‡ and on the same principle, I would make a humble attempt to ascertain the relative age of the veins of Cornwall.

Veins have been divided into two general orders, viz: *contemporaneous veins,* or those which were formed at the same time as the containing rocks: and *true veins,* whose formation is supposed to be subsequent to that of the rocks which are contiguous to them.

By a *true vein,* I understand *the mineral contents of a vertical, or inclined fissure, nearly straight, and of indefinite length and depth.* These contents are generally, but not always, different from the strata, or the rocks, which the vein intersects. True veins have usually regular walls,§ and sometimes a thin layer of clay

* Natural History of Cornwall, page 156. † Page 101.
‡ Page 51, Anderson's Translation.

§ By this term is meant, that the rock of the country stands against the vein, on each side, as a *wall,* without being intermixed, or forming one body with it.

between the wall and the vein: small branches are also frequently found to diverge from them, on both sides.

Contemporaneous veins have been usually distinguished from true veins by their shortness, crookedness, and irregularity of size, as well as by the similarity of the constituent parts of the substances which they contain, to those of the adjoining rocks, with which they are generally so closely connected, as to appear a part of the same mass. Two other marks, more distinctive, must be added. When these veins meet each other in a cross direction, they do not exhibit the heaves, or interruptions, of true veins, but usually unite. In a multitude of contemporaneous veins, some may appear to be heaved; but the apparent heave seldom affects more than one vein, and it is, in general, easy to perceive that what appear to be separate parts of the same vein, are different veins which terminate at or near the cross vein. When they meet with true veins they are always traversed by them.

With all these descriptive particulars, however, it is frequently very difficult to distinguish true from contemporaneous veins. There are few veins which can be brought to the test of all these marks; and there are probably exceptions to some of them. Some veins which are very short, are perhaps true veins; and others,

of considerable length and width, and tolerably straight, may possibly be contemporaneous; but with respect to the latter, if the dip of the strata of the rocks in which they are found be minutely examined, it will probably appear that in most cases the inclination of those veins is parallel to it, and that they are therefore contemporaneous, rather as beds than as veins. Other veins there are, of such a dubious nature in many respects, as to render it necessary to place them in a separate order.

In examining, therefore, the veins which appear on the coast, and those which have been discovered in that small portion of Cornwall which has yet been penetrated by human industry and ingenuity, I shall, in the first place, attempt to distinguish those veins whose contemporaneous formation with the rocks which contain them appears the most probable. Those which are of a doubtful nature will form the second order: the third will comprize the various classes of true veins.

FIRST ORDER.—CONTEMPORANEOUS VEINS.

I. *Granite Veins in Granite.* These may be seen in several parts of the granite coast of Cornwall; particularly at the two promontories of Castle Treryn, on which stands the celebrated Logan-rock; and Tol Pedn Penwith, which

is about a mile west of the former. They are of three kinds. Some are of considerable size, and their granite is of the same kind and colour as that of the rocks which adjoin them, but rather decomposed: they have no regular walls: several of them may be seen at Castle Treryn, and in the neighbouring rocks: one in particular, in a small cove west of the castle, about four feet wide, is visible from the top to the bottom of the cliff. There is another in the same cove, of much greater width, but not so distinct. A little further westward, another of these veins appears in a cavern, about four feet wide, with reddish felspar. Their direction is about north and south.*

There are other veins which only differ in colour from the granite which contains them: of these, a fine specimen is open to view on the eastern side of Tol Pedn Penwith: it is one foot in width, and its large crystals of felspar are of a beautiful red colour, whilst those of the adjoining granite are brownish white: it may be seen for about 40 feet in length.

The veins of the third description are composed of compact and fine grained granite, very different from the contiguous granite. These

* It is possible that most of these veins owe their appearance, as veins, to the percolation of water. The surface being lower than the adjoining country, the water has collected on it, and percolating through it in a perpendicular direction, has caused decomposition, and a consequent vein-like appearance.

are numerous at Tol Pedn Penwith: they are from six inches to a foot in width, running in all directions: when they meet each other, they do not traverse, but unite, which is perhaps, one of the best proofs of their being contemporaneous.* Veins of this kind may be seen in other parts of the granite cliff between this headland and Castle Treryn.

Some of the veins termed by the miners *Elvan-courses,* (which will be presently described,) consist, when in a granite country, almost entirely of a fine grained granite; much finer than that of the adjoining granite, although composed of nearly the same constituent parts. They may therefore be denominated granite veins, although they probably belong to the elvan formation. The elvan-course of Rosewall-hill tin mine, near St. Ives; and another, situated a little to the west of Huel Damsel copper mine, are of this description. At Cligga Point also, there is a large course, or body, of granite, which may possibly belong to the elvan formation.†

II. *Veins of Felspar.* These also may be found in several parts of the granite coast, particularly in the rocks westward of Castle Treryn. They have no walls, and although one of them

* Some of those veins are so straight and regular, they have walls so distinct, and are so easily separated from the containing rocks, that I think they are true veins, and posterior to the others.

† See "Elvan-courses" in the next order of veins.

is nearly a foot in width, they are generally very small, short, and tortuous. The felspar is very compact, and the veins may be easily distinguished by their bright red colour.

III. *Veins of Mica.* These have hitherto been found only in the granite of St. Michael's Mount. They are seldom more than half an inch wide; and although tolerably straight, are very short. They generally consist of two layers of mica in plates, which meet in the centre of the veins.

IV. *Veins of Shorl.* These have been found in both granite and slate.* In the former, at Castle Treryn and the neighbouring rocks, where they are seldom more than an inch wide, and are tolerably straight, but short. They occur in slate at Botallack mine, in St. Just, particularly on the crown rock, where they vary in size from an inch to above a foot: of some the

* In the central mining district of Cornwall, the stratified rocks are, in general, composed of argillaceous shistus, or clay-slate. On some parts of the coast, especially the south-western coast, these are frequently mixed with compact hornblende rocks, with which they often alternate. In the western part of St. Just, the rocks which overlie the granite are mostly composed of compact and slaty hornblende rock, which has been of late commonly denominated *greenstone*, although in much of it there is little appearance of felspar. The slaty rock rather merits the name of hornblende-slate. As, from the situation of all these rocks, there is good reason to suppose they belong to the same formation, I shall, in this paper, use the term *slate* for the whole.

The clay-slate is, in many parts, overlaid by greenstone, particularly near Cuddan-point, in Mountsbay, where the slate dips towards the south: the junction here is more distinct than I have seen it any where else in Cornwall.

inclination is parallel to the dip of the slate; but of others it is different.

In a part of Botallack, called the Bunny, at the junction of the granite and slate, are some large bodies of tourmaline, called by the miners "floors of cockle:" these cannot be denominated veins, and the relative period of their formation is doubtful, as they occur between the two rocks, and tin has been found under them.

V. *Veins of Shorl-rock.* I should have made no distinction between shorl and shorl-rock, had not the latter obtained a separate place in Jameson's classification of rocks. The contemporaneous veins of this rock are found only in granite: one of them, at Castle Treryn, is nearly two feet wide: it has no distinct walls, is highly inclined, and very short: they may, however, be seen on a larger scale in the rocks near Rosemodris, about five miles south-west from Penzance, near the junction of the granite and slate; some of them are two feet wide, and may be seen crossing the granite rock for at least 100 yards in length, but they do not enter the slate: when they meet each other, they usually unite. The veins of shorl-rock which occur in the slate, as at Zennor, appear to be true veins, as there is a perfect line of separation between the veins and the slate, and they invariably traverse the granite veins which appear on that coast.

VI. *Veins of Quartz.* I include in this class only the small quartz veins which, in almost all the western part of Cornwall, intersect the slate, the greenstone, the greywacke, and the granite, in all directions; the slate and the greywacke more generally than the others. Most of these veins have no distinct walls, and are irregular in size, direction, and inclination. They are intersected by all true veins, and frequently, when in slate, by the granite veins, as at Mousehole, and St. Michael's Mount. When two or more of those veins meet, they generally unite, and shew no kind of interruption.* On those parts of the coast where the slate and the granite meet, the same contemporaneous quartz veins rarely, if ever, appear in both rocks; but usually end with one of them.

VII. *Veins of Actynolite and Thallite.* These occur in the slate rocks on several parts of the coast of St. Just, between Cape Cornwall and Pendeen Cove:† also, in the slate rocks between Penzance and Chyandour. In the Greeb,

* In some instances, one of those veins appears to be heaved by another. It is probable however, as has been already observed, that what appear to be opposite parts of the same vein, are the terminations of different veins.

† At Cape Cornwall those veins are from two to eight inches wide. At Botallack, there is a vein of thallite, distinctly crystallized, about six inches wide, on the crown-rock, but in a part very difficult of access.

an insulated slate rock near St. Michael's Mount;* and in the greenstone cliffs near Cuddan-point.

The veins of Actynolite are, in general, very short, and are neither straight, nor regular. They may probably be found in the slate rocks on many other parts of the coast of Cornwall. I have never observed them in granite. A small vein of decomposing actynolite crosses a large vein of axinite, in the rocks near Huel Cock, in St. Just.

VIII. *Veins of Axinite.* There are some veins of this mineral in the greenstone rocks at Cuddan-point; but the principal veins are in St. Just: the largest which I have seen, occurs in the cliff near Huel Cock: it is three feet wide, and may be seen for perhaps twenty yards in length. In this vein have been found specimens which may vie with those of Dauphiny. Its direction is about north-east and south-west, and it underlies rapidly towards the south-east. This is the only vein of which the axinite has a violet colour. Several smaller veins may be seen in the same rocks, and also in the rocks between Huel Cock and Botallack: these however are, in general, very short and tortuous. In the crown-rock, there appear, at first sight, numerous veins of this mineral, from a quarter of an inch to an inch

* In the Greeb is a vein of asbestus-actynolite, mixed with axinite, from four to twelve inches wide.

in width, inclining towards the west; but on examination, it will be found that their inclination is at the same angle as the dip of the strata of the rock: they must therefore be considered as beds.

IX. *Veins of Garnet-rock.* One of these occurs in the crown-rock at Botallack, which consists almost wholly of garnet, and abounds in irregular crystals of that mineral. In one part it is almost a foot in width: it runs nearly north and south, but is very short. The crown-rock, which contains it, appears to be composed of slate, greenstone, garnet-rock, shorl, axinite, and many other minerals. Another large vein of garnet-rock occurs in the slate rocks of Huel Cock Carn, adjoining the large vein of axinite: its direction and underlie are the same as those of that vein, but it is very short. Other veins may be seen near a rocky headland called Carn Boscawen.

X. *Veins of Prehnite.* The only spot in Cornwall where these have yet been found, is between Botallack and Huel Cock, in the slate rocks. They are very irregular, both in size and direction: I have not seen more than two of them, the largest of which is from two to six inches wide: the inclination of one of them is very great, and is nearly the same as the dip of the strata; but that of the other appears dif-

ferent. Asbestus and stilbite have been found in the veins, with the prehnite.

XI. *Veins of Chlorite.* The chloritic slate of the Relistian Mine, in Gwinear, contains numerous minute and short veins of chlorite, which, although they occur in the neighbourhood of a chlorite tin lode, yet, from their situation and position, they can only be regarded as contemporaneous. I have also observed veins of foliated chlorite, in the chlorite of the tin lode. Veins of chlorite also occur in greenstone at the Wherry tin mine.

XII. *Veins of Iron-stone or Ire-stone.* This stone, to which the name of Iron-stone has been given on account of its extreme hardness, appears to consist, principally, of very compact hornblende, with chlorite and quartz. Few veins of this stone have yet been discovered, much to the satisfaction of the miner, to whom they are, above all things, the objects of hatred. They are generally very large, and run nearly east and west. The principal of those veins is about 20 fathoms wide, and is supposed to extend several miles in length, eastward from Roskeere, in Camborne. Another vein of it has been found in Tincroft mine, about the same width; and a third, about ten fathoms wide, a little to the south of Huel Neptune: the latter becomes much wider as it extends eastward. These veins are highly inclined, especially the

last mentioned; but whether their inclination is the same as that of the adjoining strata, has not been ascertained. They are all in slate, in which also are sometimes found detached masses of iron-stone. Very little is known respecting these veins, nor is our knowledge likely to be increased.

XIII. *Veins of Serpentine.* I have observed veins of this mineral crossing the greenstone at Porthallow, in St. Keverne, in all directions: and it is singular that, although the veins of serpentine enclose minute veins of steatite, the latter seldom appear in the greenstone. In many parts of the serpentine district near the Lizard, it is common to observe veins of one colour crossing a mass of a different colour. At Pradannack, a mass of blueish-green serpentine abounds in veins of a bright red colour At Gew Grease, where the soap rock occurs, there are veins of a greenish colour crossing the other serpentine. These veins are generally very short and tortuous.

XIV. *Veins of Greenstone.* The greenstone of St. Keverne contains veins of the same mineral, some of which are more compact than the containing rock, and others less so. Veins of greenstone may also be found in the serpentine on Goonhilly downs. They are generally very small and short, and are too closely con-

nected with the rocks in which they are found, to allow the idea of their being true veins.

XV. *Veins of Asbestus.* These may be seen in almost all the serpentine formation of the Lizard: some of them are as wide as half an inch; but their width, in general, is that of a line, running in all directions. At Gew Grease some veins may be seen upwards of an inch wide. The principal veins, however, occur at Kennack Cove, about three miles north-east of the Lizard, in greenstone: here there are some so wide as three to four inches: their position is sometimes quite horizontal. Veins of asbestus occur also in the greenstone, and serpentine of Clicker-tor near Liskeard.

XVI. *Veins of Agate.* I believe the only spot where these are to be met with, is between Kynance Cove and the Lizard, in the serpentine, near its junction with the clay-slate. They are very minute and irregular. They were discovered by Mr. Majendie, who has noticed them in his paper on the geology of the Lizard.

XVII. *Veins of Calcareous Spar in Limestone.* These occur in slaty limestone at Crantock, and near Padstow; and in transition limestone in the parishes of Veryan, South Petherwin, Menheniot, Warleggan, and Newport; and also on the northern side of Mount Edgcumbe. I believe the contemporaneous formation of such veins

has not often been doubted. They are so common wherever transition limestone occurs, that a particular description of them is unnecessary.

The veins which have been hitherto described (with the exception of those of chlorite and iron-stone) may all be denominated rock-veins. There are however, other veins which appear under different circumstances, and must not pass unnoticed. These may be styled *veins within veins*, as they are found only in the veinstones of other veins. They are probably contemporaneous with those parts of the other veins in which they are found, although perhaps not always so with the rocks which contain those veins.

XVIII. *Veins of Jasper.* I believe this mineral has hitherto been found in Cornwall, only as a constituent part of some lodes, or metalliferous veins. It has thus been found in the tin and copper lode at Botallack, where veins of yellow and greenish jasper are frequently seen crossing the coarse red jasper. In Huel Stennack, and Huel London, (both in St. Just,) veins of red jasper often appear in the quartz and the mixed stone of the tin-lodes, but are seldom larger than a quarter of an inch. In the lode of Ding Dong tin mine, minute veins of red and black jasper in quartz, are not uncommon. All these veins are very short, and appear in all directions and positions.

XIX. *Veins of Opal.* I have observed these only in one part of St. Just, viz. in the old heaps of Huel Stennack and Huel London. They occur in the dark quartz of the tin lodes, and are in general very minute and short. Some of the opal is of the kind which is known by the name of fire-opal, and is of a blackish yellow colour. The lodes which contain the veins of opal and jasper are in granite.

XX. *Veins of Fluor-spar.* This mineral has occurred in Cornwall only as a veinstone of the metalliferous veins, and is commonly of a white or green colour: but in one of the lodes of Botallack, it has been found very similar to the fluor of Derbyshire, having purple veins of the same substance running through it in all directions.

Those are all the veins which I have yet met with, of whose contemporaneous formation there is the greatest probability: a further and more minute examination will perhaps bring others to light. But although they may all be contemporaneous with the rocks which contain them; it does not follow that they are all of the same age: on the contrary, as some are found in granite; others in slate; others in greywacke; others in serpentine; and others in limestone; their ages must be as different as those of the containing rocks.

SECOND ORDER.—DOUBTFUL VEINS.

This order will comprehend all the veins, whose situation, appearance, and attendant circumstances, render it doubtful whether their formation was contemporaneous with, or posterior to, that of the rocks which contain them. In this order may be classed,

I. *Granite veins in Slate.* These have been discovered in no less than fourteen places on the coast of the western part of Cornwall, between Porthleven and St. Ives Head, viz. (beginning at the most eastern point.)

1. About half a mile eastward of Trewavas Head, in the parish of Breage.*

2. On the eastern side of Portcue Cove, in the same parish.

* Those veins are the most gigantic, as well as the most distinct, and regular, of any in Cornwall. Their edges appear in the perpendicular cliff; and being very white, and the slate very dark, the contrast is striking. They are all highly inclined: the three largest are eight feet wide: their direction is nearly north and south, and they underlie rapidly towards the east: their edges may be seen on the underlie, for 150 yards: in the upper part, some of them become united, and appear to join a mass of granite, about 40 feet thick, which reposes horizontally on the slate. This mass has been considered by some geologists as the result of the union of several granite veins, and therefore as belonging to the same formation as the veins. The union of the veins with the mass has not, however, been ascertained, although it is very probable; for at the point of junction, the rocks are inaccessible, and are covered with weeds and muddy sediment. The slate strata are horizontal: the veins therefore interrupt them; but they come nearer to the lines of the slate than any others I have observed. One of them contains fragments of slate, and they all contain a very large proportion of quartz, with scarcely any mica.

3. On the western side of the same Cove.*

4. At St. Michael's Mount.

5. At the village of Mousehole.

6. At Rosemodris, three miles south-west of Mousehole. †

7. At Carn Silver, about half-a-mile west of Rosemodris. ‡

8. Near Whitesand-bay, between the Land's-end and St. Just.

9. At Porth Just, joining Cape Cornwall on the south. §

10. At Polladan Cove, joining the same Cape on the north.

* At the most western point of this cove, the slate, instead of being closely united to the granite, appears as if it were simply and loosely laid upon it.

† At this spot the slate which adjoined one of the granite veins is fallen off from one side of it, for several yards in length, and has left it completely exposed.

‡ Here the slate, which occupies about half a mile of the coast, appears to fill a granite basin; for at the eastern point, the granite underlies to the west at an angle of 25 degrees; and at the western point it underlies to the east at an angle of 60 degrees from the perpendicular. On this spot there is an instance of a granite vein penetrating the main body of granite. A small mass of slate incumbent on the granite, has a granite vein, about four inches wide, running through it; and on each side of it, the vein may be traced for several yards in the granite: on the eastern side, at a little distance from the slate, it has the appearance of a vein of shorl-rock: this will shew the near connexion which subsists between shorl-rock and granite.

§ Here, and at Polladan Cove, the granite, in several parts, appears insulated in the slate; but from the relative situation, and size of those apparent bunches, they probably belong to different veins, whose continuity, at the surface, has been either prevented, or broken, by the slate. The large vein at Porth Just, six feet wide, appears to me to be, not a granite vein, but an elvan course.

11. At Chycornish Carn, near Botallack.
12. At Pendeen Cove, in St. Just.
13. At Polmear Cove, in Zennor.*
14. At the Cove north of Zennor church.

As the veins in several of these places have been described in the first volume of the Transactions, I shall only give, in notes, a few particulars of those which are most remarkable, and which have not been already noticed.

The relative age of those veins has been a subject of as much discussion as almost any point in geology; especially as it appears to involve several other points, which are deemed, by different parties, of essential consequence to their systems. I believe the more they are examined, the more difficult it will be found to form any consistent theory respecting them: in order, however, to be convinced of this, it is necessary to examine them at every place where they have been discovered; for so different are their appearance, and attendant circumstances, in different parts, that a very plausible theory made with reference to the veins of one spot

* These veins are as singular, and as interesting, as any in Cornwall. They are from the smallest possible width to nearly two feet: they run in several directions: some of them are vertical; others are inclined at different angles, and some are completely horizontal. In one part of the cove, where one of the veins inclines at an angle of full 45 degrees, the slate is fallen from the upper side, and has left a part of the veine xposed to view. Near the same spot is an apparent intersection of one granite vein by another, each of which is about a foot wide. One of them appears to be heaved five feet to the left,

only, will be found quite inconsistent with those of another. From the whole, however, the following facts may be collected.

1. They occur only at, or near, the junction of the granite and slate.

2. They are not metalliferous.

3. They have no general direction or position. At Mousehole, and Polladan Cove, they run east and west: those at St. Michael's Mount,* and some at Porth Just, run W. N. W. and E. S. E.: those at Polmear Cove, north and south. Some are quite vertical, as at Portcue, Rosemodris, and Polmear Cove: those at St. Michael's Mount and Mousehole are nearly so: others are inclined at different angles, as at Trewavas Head, Porth Just, and Chycornish Carn; and others quite horizontal, as at Polmear Cove: at the latter place, indeed, they may be seen in almost all positions.

4. Their direction is usually as straight, and their size as regular, as those of true veins; but in some cases they become smaller as their distance from the granite mass increases.

5. Their greatest length has never been ascertained: some at Rosemodris may be traced

* Dr. Berger asserts (Geol. Trans. Vol. 1. page 146.) that the granite veins are invariably directed from north to south: surely this was a slip of his pen, as the veins at the Mount, which was the principal object of his attention, must have convinced him of the contrary. These veins are from half an inch to a foot wide, and underlie a little towards the north.

in the slate nearly 200 feet, and are then lost in the sea.

6. The granite of the veins generally appears different from that of the main body; it is of much smaller grain: it contains a much larger proportion of quartz, and very little mica: sometimes indeed, no mica at all.

7. The slate which is contiguous to the veins becomes almost imperceptibly changed from clay-slate to mica-slate, and sometimes has even the appearance of gneiss.

8. The slate which is close to the veins, is frequently much harder than that which is more distant from them, and its texture is, in general, not so slaty.

9. At St. Michael's Mount, and Polmear Cove, the veins may be traced to the granite mass, with which they appear to be in complete union, and to form one body, losing entirely their character as veins. Whether the other veins unite with the granite mass or not, has not been ascertained, as the point of junction is seldom accessible, or even visible.

10. At Carn Silver, one of the veins may be traced from the slate *into* the granite mass. This is the only instance which I have discovered of a granite vein penetrating both the slate and the granite.

11. Some veins (as at Carn Silver, Chycornish Carn, and Pendeen Cove,) are closely

connected with the slate, and the two bodies appear intimately united, and inseparable. In fact they appear contemporaneous. Others (as at Trewavas Head, the western side of Portcue Cove, Rosemodris, and Polmear Cove,) are so easily separable from the slate, and have walls so distinct, that, under any other circumstances, they would be taken without hesitation for true veins.

12. Fragments of slate are visible in several of the veins, as at Trewavas Head, St. Michael's Mount, Mousehole, Porth Just, &c. I have not observed them in the main body of granite.

13. At Mousehole, and at St. Michael's Mount, the slate is intersected by numerous small quartz veins, some of which are traversed by the granite veins: others, on the contrary, traverse and heave both the granite veins, and the other quartz veins.*

14. At Mousehole, and Whitesand-bay, where a junction of the main bodies of granite and slate takes place, they appear, at some points, so completely intermixed, as almost to exclude any other idea than that of contemporaneous formation, although, at other points, the junction is distinct and regular.

* At Mousehole, one of the granite veins is heaved three feet to the left, by a quartz vein, in which slate is mixed with the quartz. By another, two granite veins are heaved to the left: one nearly three feet; the other, six inches: the two latter heaves occur nearly at low water mark.

15. In most other places where the junction occurs, the slate reposes on the granite, without any appearance of a dislocation, or disturbance of the strata: particularly at Portcue Cove, Carn Silver, and Polmear Cove.

Now from these facts, taken separately, very different conclusions might be, and have been, drawn.

From the union of some of the veins with the granite mass at St. Michael's Mount, and at Polmear Cove, it has been concluded that the veins and the mass are contemporaneous: if so, was the whole formed before, or after the slate? Before; says Dr. Berger; who, on viewing the veins at Mousehole, and at St. Michael's Mount, which are nearly vertical, concludes that they were ridges protuberating from the mass of granite, the spaces between which were afterwards filled with the slate: had he, however, seen the horizontal veins at Polmear Cove, and the highly inclined veins near Trewavas Head, he would have found them decidedly opposed to such a conclusion.

Dr. Thomson and Mr. Allan, on the contrary, (from an examination of St. Michael's Mount,) unite in the supposition, that both the veins and the mass are posterior to the slate, although they widely differ in opinion as to the mode of their formation. The former thinks that the

whole is transition granite.* The latter contends that both the mass and the veins were thrown up from beneath. In the former case, the whole of the granite must have been deposited on the slate. In the latter, could it possibly have been thrown up from below the slate in a fluid state, and yet not have run over any part of it? and would not the fragments of slate be as common in the mass as in the veins? I apprehend, however, that in no part of St. Michael's Mount is the slate to be found under the granite.†

From the intimate union which subsists between some of the granite veins and the slate

* (Annals, vol. 2, page 253.) As there is not a single visible point of junction of the granite and slate on all the coast of Cornwall, where there are not granite veins intersecting the slate; we may fairly conclude on the existence of similar veins at those points of junction which are hidden from our view. If Dr. Thomson's inference, therefore, be correct, that the granite veins at the Mount, prove the whole granite mass to be transition granite, and posterior, in point of formation, to the slate; it will equally apply to all the granite of Cornwall: or at least to all those parts where the veins are in union with the main body of granite. If this, however, were the case, should we not long since have discovered, in our deep mines, other rocks under the granite?

† Dr. Thomson says that on the west side of the Mount, there are two beds of granite in the slate, in such a position as to prove that the great body of granite was deposited after the slate. It does not appear to me that those granitic bodies can, with any propriety, be called "beds in the slate." One of them is a granite veiu, and although six feet wide near the granite mass, it becomes gradually smaller as it recedes, and dwindles to a point at the distance of 80 feet. The other is a part of the granite mass, from which some veins appear to diverge, and in no part does it overlie the slate.

which contains them, it has been contended by other geologists, that the veins and the slate are contemporaneous: To this, some would reply by asking, how came the fragments of slate into the veins? and how could some of the quartz veins in the slate be traversed by the granite veins?

Others have cut the knot which they have found so difficult to untie, and declared the whole mass, consisting of the main bodies of granite and slate, the granite veins, and all the other veins which appear in the mass, to be contemporaneous.

Others, however, have come to a different conclusion. They argue, 1. from the fact of some of the granite veins traversing the contemporaneous quartz veins; and 2. from the fragments of slate which are frequently found in them; that *the granite veins are of a more recent formation than the slate which contains them.* They also contend, 1. from the granite of the veins being generally different, in many respects, from that of the mass; 2. from the fragments of slate not being found in the mass as well as in the veins; and 3. from the slate being rarely, if ever, overlaid by any part of the granite mass; * that *the main body of granite may*

* Instances of granite fairly overlying the slate (except in the case of the granite veins) are very rare in Cornwall. The mass reposing on the slate near Trewavas Head, is the most conclusive; but even that has been disputed. The granite at Cligga Point (if it is not a

have preceded the slate, although the granite veins (as veins) may have followed it.

If the whole of the veins which have been described were subject to one general conclusion, the last would, perhaps, appear the most reasonable; but the circumstances in which they are found are so diverse, that it is possible they may not all bear the same relation to the containing rocks; and that their formation may have taken place in different modes, and at different periods.

There are several mines in Cornwall in which the slate (killas) and the granite meet. In some

large elvan course,) might be called secondary or transition granite, without affecting the age of the granite of other parts of Cornwall, as it is far from the large granite chain: The apparent alternations of granite and slate at Dolcoath, Cook's Kitchen, and Tincroft, may be caused either by the occurrence of highly inclined granite veins, or by the slate filling up the irregularities in the granite. What has been called granite at Huel Fortune is evidently an elvan course. But even were this alternation more general, it would only prove that in Cornwall, as in other countries, two primitive rocks, at, or near, the point of their junction, sometimes alternate with each other: and does not this render it probable that although, in strictness, the main body of the one may be said to be anterior to that of the other, the formation of the former was scarcely finished when that of the latter began? How else can we account for the fact, that the extremities of the granite and clay-slate exhibit a change in some of their qualities, almost wherever a junction occurs? In this view, the extremities of the two bodies may be said to be contemporaneous. In the present case, the body of slate which is intersected by the granite veins is so comparatively small, that we may perhaps form an idea of the formation of the surface of the granite mass, the thin body of slate, and the granite veins, following so closely on each other, as to render the whole, as nearly as possible, contemporaneous: the union of the veins and the mass might thus have been easily formed.

of these, viz. Huel Unity, Huel Gorland,* Treskerby, Tincroft, Cook's Kitchen, Dolcoath, and in some of the St. Just mines, the lode (or metalliferous vein), when near the point of junction, has one of its walls of slate, and the other of granite. In some cases, this is probably owing to the occurrence of granite veins in those mines, a granite vein being one of the walls of the lode.

From the occurrence of granite veins in the slate, wherever the junction of the two rocks has been discovered on the coast, and from their probable existence in the mines in which both the rocks occur; it is very likely that if the lines of their junction throughout Cornwall could possibly be laid open to view, granite veins would be seen traversing the slate, at almost every point.

II. *Veins of Steatite.* These are very plentiful in the serpentine of the Lizard, particularly in the parish of Mullion. Near the village of Pradannack is a vein from one to two feet wide:

* Dr. Berger (Geol. Trans. vol. 1. page 146.) says there are granite veins called *lodes* by the miners, running north and south, in Huel Gorland and Dolcoath. I cannot find that such is the fact. Indeed I am not aware of a single metalliferous granite vein in the whole of Cornwall. There are lodes in Huel Damsel, Huel Jewel, Huel Virgin, and in some mines in St. Just, in which granite is occasionally found in bunches; but these are all in a granite country. I have seen the red oxide of copper in granite from Huel Damsel, and the oxide of tin from St. Just, but the granite was either from the walls, or from occasional bunches in the lodes. I do not recollect an instance of a metalliferous vein being traversed by a granite vein.

their principal locality, however, is Gew Grease, better known by the name of the Soapy Rock, where they are from six inches to three feet wide, running north-east and south-west, and underlying towards the south-east. On following some of the veins upwards, the back, or top, will be found to consist almost wholly of quartz. Other veins occur at Pentreath, between Gew Grease and the Lizard, and also near the village of Cadgewith; but they are seldom larger than a few inches. Their colour varies from white to yellow, green, and purple. The veins of steatite have distinct walls, and are as regular as most true veins. Fragments of serpentine and calcareous spar are sometimes found in them. I consider them, therefore, as true veins; but I have placed them in the doubtful order, because some geologists, whose judgment is entitled to respect, are of a contrary opinion. Dr. Berger thinks that steatite bears the same relation to serpentine, as kaolin does to granite: * and Dr. Thomson supposes the steatite is a portion of the serpentine, altered by the action of water, or some other cause. † Sir H. Davy, however, considers those veins as mechanical deposits. ‡

I have lately observed veins of white steatite in the slate rocks at Pendeen Cove, in St. Just.§

* Geol. Trans. vol. 1. page 131. † Annals, vol. 2. page 251.
‡ Cornw. Geol. Trans. vol. 1. page 143.
§ The rocks in this Cove have more of the nature of clay-slate, than any others in St. Just.

These also, although most of them are very small, want that close connection with the containing rocks, which is generally essential to contemporaneous veins.

III. *Veins of Calcareous Spar.* The veins of this mineral which have been already described (in limestone), will probably be easily admitted into the contemporaneous order. Those which occur in other rocks are more doubtful. 1. In serpentine: these may be seen principally at Gew Grease, and at the junction of the slate and serpentine near the Lizard Point: they are in general small; some are short and tortuous, but others are straight and regular, and have distinct walls: the carbonat of lime, which is frequently fibrous, is easily separated from the rock. 2. In slate: the rocks, on the coast of St. Just, from Cape Cornwall to Pendeen, contain numerous veins of this mineral, in which it occurs both massive, and crystallized in different forms; although they are small and short, they are in general tolerably straight, and have regular walls. 3. In the Greywacke, near Padstow, veins of calcareous spar are visible, very similar to those which occur in the serpentine.

IV. *Elvan Courses.* From the great width of many of these, they are termed by the miners channels, or courses, rather than veins. They are generally composed of a mixture of horn-

stone, quartz, and felspar; having the appearance of hornstone porphyry. Other substances, however, are called *elvan* by the miners: thus; a stone composed of very compact hornblende and chlorite is called *blue elvan* in Huel Ann: a mixture of hard hornblende and quartz has the same name at Botallack: a compound of felspar and hornblende is *elvan* at Gwallan, and is as soft as the neighbouring country: a mixture of hornstone, quartz, shorl, and chlorite, forms the *black elvan* of Chasewater; and it has been already mentioned that fine grained granite is the *elvan* of Rosewall-hill. Hardness is not an essential quality of elvan.

In Chasewater copper mine, and in the Wherry tin mine, elvan may almost be called a veinstone, as small veins of copper and tin proceeding from the lodes, are frequently found in the elvan courses. In the Wherry, it had the name of "stannified porphyry." In a part of Huel Unity, the elvan is so rich in tin, that it is considered as the tin lode.

The elvan courses vary in width from one to sixty fathoms, or 360 feet.* Their direction is generally a little north of east, and south of west,† and they almost always underlie to-

* The elvan course in Huel Alfred is in some parts 60 fathoms wide, but in general not more than 50.

† I have heard of very few which have a different direction. There is one in Ting-tang copper mine, another in Huel Fortune tin mine, and a third in Ludgvan, which run south of east and north of west.

wards the north: perhaps on an average, a foot to every foot in depth, or at an angle of 45°.* The extent of their length has never been ascertained, although one of them has been traced five miles. They furnish most of the building stone of the neighbourhood.

The elvan courses of Cornwall are generally called by geologists, porphyry dykes; but there is an essential difference between them and the dykes of the north of England. The latter intersect, and frequently heave, both the lead lodes and the coal strata; but the elvan courses intersect no true veins. †

Elvan courses may be seen at the surface almost wherever a quarry of building stone is opened in a slate country; but the spot where they may be viewed most advantageously, is the cliff between Trevellas Head and Cligga Point, in St. Agnes: there are there four elvan courses, all open to the day, to the extent of their whole width, and for a considerable length: the first, which may be seen from Trevellas Head, overlies a part of the slate cliff: the three next form a considerable part of Cligga Head-land. Beyond these is the mass which forms Cligga Point,

* I know only two or three which underlie towards the south. In the Wherry tin mine, formerly wrought under the sea near Penzance, the underlie is, in some parts, two fathoms, to one in depth: an underlie so great, that the workmen would actually walk up its southern wall.

† One instance to the contrary has been discovered in Polgooth, which will be presently noticed.

and which is, probably, from 150 to 200 fathoms in width, overlying the slate. On the surface, and for a considerable way down the cliff, it appears to be decided granite; but in the lower part of the cliff it assumes an elvan appearance. It has, therefore, been called by some, a secondary formation of granite, and by others, a part of a granitic elvan course.* This mass, when viewed at a small distance, appears to be obliquely stratified; but on a nearer approach, the dark lines which appeared like breaches between the strata, are found to be small veins of blackish quartz, whose contemporaneous formation can scarcely be doubted. Many of those veins contain tin, and the numerous holes made by the miners in different parts of the rock, in order to get at the tin, together with the large and sharp ridges which have been made by taking away the veins, give the whole, when viewed from the bottom of the cliff, a most romantic, as well as terrific appearance.

Elvan courses have been considered as contemporaneous with their enclosing rocks, because they are traversed by metalliferous and other veins, in nearly the same manner as the

* It is not improbable that all those elvan courses become united between Cligga Point and the headland north of St. Agnes pier, and afterwards assume a more westerly direction, as, in the cliff near the old tin mine of Polberrow, a large granitic elvan course is visible, which has been traced as far west as Huel Coates, where it is quite decomposed, and contains so much felspar, that a large quantity of china clay has been extracted from it.

slate and the granite: this, however, only proves their priority to those veins. It has also been alleged that elvan has been found in floors, as in Crenver and Penberthy-Crofts mines; and in bunches, as in the United mines, and Huel Squire, which are all in slate. It is probable, however, that what the miners call *floors*, are elvan courses, greatly inclined; and it is questionable whether, if the *bunches* were traced, they would not be found connected with neighbouring courses. I have never heard of bunches of elvan, except in the neighbourhood of elvan courses.

It must be observed on the other hand, in favour of their posterior formation, 1. that they do not always underlie in the same direction, and scarcely ever at the same angle, as the dip of the slate.* 2. Some elvan courses have been discovered partly in slate, and partly in granite, as in the copper mines of Tresavean and Treskirby.† 3. Fragments of slate are found in elvan courses close to their walls, or their junction with the slate country. 4. The elvan

* The elvan course of the Wherry mine underlies north, whilst the slate dips south-east. This course may be distinctly seen at low water, just behind Penzance pier, and it is what Dr. Thomson alludes to, when he says "Beds of a granitic rock are seen rising out of the sea just behind this pier." (Annals, Vol. 2. page 347.) The elvan courses at Cligga all underlie northwards, but the slate dips rapidly towards the south.

† The elvan courses in those mines are harder when in the granite, than when in the slate.

course in Polgooth tin-mine traverses and heaves all the veins which it meets with, except a flukan vein, by which it is itself heaved.*

These are all the circumstances which occur to me, either in favour of, or against, the contemporaneous formation of elvan courses. The result of the whole appears strongly in favour of their being true veins, of which they probably form one of the earliest classes. †

Tin lodes are, in general, richer or poorer in the elvan, than in the adjoining rocks, in proportion to the hardness or softness of the elvan. In Rosewall-Hill, where the elvan was hard, the lode became poor; but in Huel Vor, where it was soft, the lode improved. Copper lodes are generally as rich, and frequently richer in the elvan, than in the slate, or the granite; as at Treskirby, Huel Alfred, and Nangiles. At Tingtang, the lodes are richest when they are between the slate and the elvan.

V. *Veins of Oxide of Tin.* I have considerable hesitation in placing any of the metalliferous veins in the contemporaneous order: yet there are some which present a very doubt-

* This elvan course may be more recent than the other veins, but as it is a solitary instance, it cannot affect the age of other elvan courses. See a paper by John Hawkins, Esq. in Vol. 1. page 143, on the Lodes of Polgooth.

† In my paper on Elvan courses, in Vol. 1. I supposed them to be of the same age as the adjoining rocks. I have here inclined to a different opinion, and have stated the grounds of it.

ful appearance. The greatest part of the veins which contain this mineral are evidently true veins; but it is probable that some of the smaller contemporaneous veins of quartz are metalliferous, and contain the oxide of tin, as at St. Michael's Mount, and Cligga Point. The veins, however, to which I particularly allude, are situated in the Sealhole mine, in St Agnes, and are composed entirely of oxide of tin. They are extremely minute, and run east and west. I have a piece of slate containing several of these veins, some of which are not larger than the fiftieth part of an inch: and they so thickly intersect the slate, and are so closely connected with it, as to make their origin appear very doubtful.

The apparent veins of magnetic iron pyrites, which are numerous in the Crown rock at Botallack, had they been really veins, would, perhaps, find their place in the doubtful order: they are from one to two inches in width; but as their inclination, which is towards the west, is exactly conformable to the dip of the strata of the rock, they must rather be considered as beds.

THIRD ORDER.—TRUE VEINS.

This order comprises all that are generally acknowledged as true veins, especially all the

lodes. These may be divided into several classes, the periods of whose formation appear to be different.

Before I attempt to distinguish those classes, it will be necessary to define the terms which are generally applied by the miners to the different kinds of lodes.

By a *lode*, I mean a metalliferous vein.*

By *east and west lodes*, metalliferous veins whose direction is not more than 30°. from those points.

By *contra lodes*, metalliferous veins whose direction is from 30°. to 60°. from east and west.

By *cross-courses*, veins whose direction is not more than 30°. from north and south.

By *flukan veins*, veins of whitish or greenish clay, generally argillaceous.

By *cross flukans*, veins of this clay having the same direction as the cross courses.

By *slides*, veins of slimy clay, greatly inclined, having generally an east and west, and rarely a north and south direction.

The FIRST CLASS of these veins, in point of age, consists, probably, of *the oldest tin lodes*. I have divided the tin lodes into two classes, because several instances have been discovered, in which, at the meeting of two tin lodes, one of

* The name *lode* is given by the miners to every vein which appears likely to produce metallic substances.

them is traversed and heaved * by the other. It may be stated in general, (although not without exceptions,) that the tin lodes which underlie northwards, are traversed by those which underlie towards the south. I conclude, therefore, that the former, which form a very large majority of the whole, are the oldest. In this class are included most of the lodes in the tin parishes of St. Agnes and Wendron, and a considerable number of the lodes of St. Just; those also in the mines of Huel Vor, Hewas Downs, Huel Unity, Pednandrea, Relistian, Trevaskus, Nangiles, &c.

That these lodes are traversed by other tin lodes which underlie in an opposite direction, may be seen in Huel Trevaunance, (Plate II. fig. 5.) Sealhole, Huel Coates, and Huel Owls. †

* I use the term "*heaved*" as applicable only to a longitudinal shift of the vein, and "*thrown up*," or "*thrown down*" to those shifts which take place on the meeting of two veins, underlying in different directions, in their downward course.

In describing the heave of lodes as *to the right*, or *left*, I mean that when lodes are heaved by other veins, they may be found on the other side of the traversing veins, by turning either to the right, or left hand. I use these terms in preference to the points of the compass, because, in whatever direction a miner may pursue a lode, a right, or a left hand heave, is precisely the same on both sides: but a heave to the north, south, east, or west, supposes that on one side of the traversing vein, the lode is in its original direction, whilst on the other side, it is heaved: but although this is probably the true state of the case, it is not easily discoverable, unless the heaves are considerable, on which side a lode has been shifted from its proper course.

† In Sealhole, the great tin lode, which underlies south, traverses three tin lodes which underlie north, and throws all of them up two

SECOND CLASS. *The more recent tin lodes,* in which are comprised most of those which underlie southwards. To this class probably belong a few of the lodes in St. Agnes, and a considerable number in St. Just.* Those of Poldice, Huel Peever, Treskirby, Gwallan, &c. have a southern underlie; but they have not been seen in connexion with lodes which underlie in an opposite direction.

A particular description of tin lodes will be found equally applicable to both these classes.

Their veinstones are various. In some cases quartz, as in Huel Gorland, the great tin lode in Poldice, the Little Minver lode in Polgooth, &c. In others, chlorite; as in Huel Unity, Relistian, Carleen, &c. Frequently a mixed stone, called by the miners capel, which in

fathoms. All the veins appear bent, on each side of the traversing vein. (Plate II. fig. 1.)

In Huel Coates the intersection is longitudinal. The great lode underlying south, and running nearly east and west, intersects several small lodes which run south of east, and north of west, all of which are heaved about a foot to the right.

The tin lode of Huel Owls, in St. Just, runs nearly north-west and south-east, and traverses every other tin lode which it meets.

* In the Parish of St. Just, there is a valley called Nancherrow bottom, which divides nearly the whole parish in a direction from E.S.E. to W.N.W. or nearly so on the whole, although its course is serpentine, from its commencement to the sea. South of this valley nearly all the lodes underlie north; as in Huel Bellon, Little Bounds, Huel Dower, Huel Diamond, Balswhidden, &c. North of the valley the lodes generally underlie south; as in Botallack, Huel Cock, Huel Owls, Carnyorth, Parknoweth, Huel Spearn, Boscagel, &c. Some instances to the contrary have been found on both sides of the valley; but they are very rare.

Rosewall-Hill appears to be quartz and shorl; in Huel Unity, quartz and mica; and in several lodes in St. Agnes, chlorite, shorl, and quartz. Of some lodes in St. Just, decomposed granite forms a considerable part.* Shorl and fluor are rarely veinstones of tin lodes, but tin has been found in the former at Zennor, and in the latter at Huel Malkin.

The length and depth of tin lodes, or indeed of any metalliferous veins, have never been ascertained. Their width varies from that of a barley-corn to 36 feet.† The average width may be stated at from one to four feet: it is, however, not at all regular: the same lode may vary in size from six inches to two feet, in the space of a few fathoms.

Their direction is also various:‡ generally from 5°. to 15°. south of east and north of west: in some cases due east and west;§ and less frequently, north of east and south of west.‖ The tin lodes of St. Just vary more from an

* The lodes are not composed of this substance; but bunches of it are frequently found in them, when in a granite country. It is considered favourable to tin.

† Only one lode has been found in Cornwall so large as this, and that only for 20 fathoms in length, in Relistian. In Nangiles, the tin lode is, in some parts, 30 feet wide.

‡ I give the direction as I have received it from the miners, with reference to the magnetic north. If it had reference to the true north, I have no doubt most of the veins, except those of St. Just, would appear to run north of east, and south of west.

§ In Treskerby, Huel Sparnon, Poldice, Polgooth, Huel Coates, &c.

‖ In Huel Vor, Huel Gorland, Nangiles, &c.

east and west direction, than most others in Cornwall. They point nearly south-east, and north-west, and might well be called contra tin lodes. The direction of the lodes of Polgooth is very singular. One of them points nearly north and south, and is therefore a cross course: the only instance, I believe, in Cornwall, of a cross course being rich in tin. Two other lodes point north-west, and south-east; the direction of contra lodes.*

The average underlie of the tin lodes is about two feet per fathom. The greatest underlie I have heard of is ten feet, and occurs in the lodes of Sealhole, and Huel Trevaunance: on approaching the gossan or copper lodes, their underlie increases to 16 feet. (See fig. 1.)

None of the tin lodes have been traced more than two miles in length. Those of Huel Peever and Poldice only, have been traced so far. The Huel Vor lodes have been traced about a mile and half.

Pryce observes † that in his day, tin lodes rarely continued rich, or worth working, beyond

* The contra lodes and cross course at Polgooth, all rich in tin, are traversed and heaved by the great east and west tin lode, as well as by the elvan course, and are therefore probably older than either of the latter. They must be regarded as exceptions to the general rule.

† Min. Cornub. Preface, page 8. The fact was, perhaps, that the expence of draining mines, as compared with the value of their produce, was so much greater fifty years ago than it is at present, that although lodes might have been equally rich in deeper parts, the produce was insufficient to meet the increased expence of draining.

50 fathoms deep: but of late years the richest mines in Cornwall have been much deeper. Huel Vor, which has lately produced 1500 blocks or 250 tons of tin in three months, is 120 fathoms under the surface. Hewas Downs is 140 fathoms, and is said to be more productive at that depth than in any other part. The lodes of Huel Ann were richest at the depth of 80 fathoms; Trevenen at 150, andPoldice at 120 fathoms.

In order to prove, on the principles already laid down, that the tin lodes are the most ancient of the true veins, it must be shewn that they are traversed by true veins of every other description.

1. By east and west copper lodes; as at Poldice*, Nangiles, Huel Peever †, the Pink and Blue Hills ‡, Sealhole §, North

* Here two tin lodes are traversed by one copper lode, and both are heaved about twelve feet. In Nangiles, two copper lodes traverse one tin lode, which is heaved by both of them.

† This mine presents the most extraordinary instances of the intersection of different veins, of any in Cornwall. A description of them by John Williams, Jun. Esq. is inserted in the 4th vol. Geol. Trans. The tin lode, underlying south, is met in its downward course by a copper lode underlying north, and thrown up eight fathoms. It is also traversed by two slides, both underlying north; by one of which it is thrown down 14 fathoms, and by the other thrown up nine feet, (Fig. 2.) In another part of the same mine, it is heaved 70 fathoms to the right, by two cross courses, (Fig. 3.)

‡ The tin lodes of these mines, which underlie north, are traversed by at least eight copper lodes underlying south, and thrown up by each of them.

§ Here the tin lodes are thrown up two fathoms by a copper lode, and two fathoms more by another tin lode, (Fig. 1.) A singular heave

Sealhole*, Huel Trevaunance †, &c.

I have met with no instances of tin lodes coming in contact with any other copper lodes, than the oldest east and west lodes.

2. By cross courses ‡: as at Huel Vor §, Huel Sparnon, North Sealhole ||, Huel Peever, &c.

of tin lodes by a copper lode was observed in this mine some years ago. A part of a very rich tin lode was heaved so exactly opposite to a part of an unproductive lode, as to occasion a dispute between two sets of workmen. (Fig. 4.)

In an old mine in St. Agnes, called Huel Dreath, the back, or top of the tin lode, appeared three times at the surface, by being thrown up twice on meeting with copper lodes. (Fig. 6.)

* Here the tin lode is thrown up 17 fathoms.

† Here the tin lodes underlie ten feet per fathom north, and the copper lodes three feet in the same direction: on their intersecting the tin lodes, the latter are thrown down nearly five feet. In this mine, there is a junction of tin lodes all underlying north. Trevaunance lode, and Pie lode, underlie 10 feet per fathom: the green lode only six feet. The green lode, on meeting the Trevaunance lode, is carried ten feet in the direction of the latter, and then proceeds in its former course. By the Pie lode it is carried 14 fathoms farther in the direction of that lode, and then again resumes its previous course. The lodes whilst together are easily distinguished. (Fig. 5.)

‡ The shifts of lodes by cross courses and cross flukans, must, of course, be always longitudinal.

§ In this mine there are three cross courses which affect the lode in a different way. For several fathoms on each side of the western cross course, the lode is divided into small, and almost worthless branches. The middle cross course heaves the lode 27 feet to the right. By the eastern cross course, the lode, at the depth of 20 fathoms, is heaved 42 feet to the right; but at the depth of 60 fathoms, only six feet. Some other shifts of this kind will be mentioned hereafter. A small difference in the heave, at different depths, might be owing to a difference in the underlie of the lodes, but when it is so great, can it be accounted for on any other principle than that of a slipping down, or falling off, of the upper part of the country, at a larger angle than the lower part on one side of the cross course?

|| Here the tin lode is heaved six feet to the right, whilst a neigh-

3 By cross flukans: as at Huel Vor*, Huel Unity, Huel Gorland, &c.

4 By slides: as at Huel Peever, (fig. 2.) Gwallan, Huel Vor, Polgooth, Blue Hills, Treskirby, (fig. 15.) &c.

A fine view of tin lodes of both classes, and of their intersections, may be obtained at Carclase mine, near St. Austle, which is open from the surface. The country is a decomposed granite, of a greyish white colour: the lodes, which are composed of quartz and shorl, being of a blackish colour, and seldom more than six inches wide, the contrast is very visible. The lodes of the oldest class are nearly perpendicular: some of them have a small inclination towards the south: the more recent lodes underlie rapidly southwards, and traverse the others.

When tin lodes come in contact with the junction of the granite and slate, the apparent effect is very different, in different parts of the mining district of Cornwall. In some of the St. Just mines, viz: Botallack, Little Bounds, &c. when the lodes are between the two rocks, one of the walls being granite, and the other,

bouring copper lode is heaved by the same cross course 16 feet, (Fig. 8.) The copper lode is intersected at a larger angle than the tin lode.

* Here there is a cross flukan about 15 feet from the middle cross-course. The lode was much richer between the flukan and the cross-course, than before it came in contact with either.

slate, they are richer than on either side of the junction. This is also the case in Treskirby. In Huel Unity, and Cook's Kitchen, there is scarcely any perceptible alteration in the lodes, either at the point of junction, or beyond it. But in the parish of Breage, in the neighbourhood of the granite peak called Godolphin Hill, the tin lodes are "wrung up" and almost "cut out" by the slate where it joins the granite, and vice versa. The lodes in the slate may be almost said to terminate with the slate. On the eastern side of the hill, the lode of Carleen, (a compound of quartz, chlorite, and mica,) which is a continuation of one of Huel Vor lodes, was rich in tin nearly to the extent of the slate; but nothing more than "a small string" has been found in the granite. The junction at this point is immediate, and without confusion: the slate overlies the granite at an angle of about 45°. The lodes in the granite present the same appearance on entering the slate: on the northern side of the hill, the lodes of Huel Breage, and the Great Work, (composed of quartz and chlorite,) were rich in the granite, and were wrought to its extreme point, in several levels; but nothing more than a minute branch could ever be found in the slate. The junction on this side is more confused. The granite and slate appear (as the miners term it)

jumbled together, between the decided slate, and the decided granite.*

Most of the productive tin lodes in Cornwall have been found in a slate country: as Polgooth, Hewas, Huel Peever, Pednandrea, Huel Vor, Relistian, Trevaskus, and all the St. Agnes mines. The lodes of Wendron are generally in granite. Those of St. Just, in both.

Besides tin, the ores of other metals, which are generally supposed to be some of the oldest, have been found in tin lodes, viz. Wolfram, in Poldice and Relistian, and also in a lode at Kit-hill: mispickel in Relistian †; and native bismuth in Botallack. Phosphat of iron, also, has been found in some of the small tin lodes of Huel Kine, in St. Agnes. Chalcedony was found in the tin lodes of Trevaskus and Pednandrea; and jasper in that of Ding Dong.

THIRD CLASS. *The oldest east and west Copper lodes.* These form the great majority of all the copper lodes of Cornwall.

* In one part of Tregoning Hill the granite appears to be regularly stratified.

† In this mine was discovered, in the tin lode, at the depth of 75 fathoms, a mass of chlorite shist pebbles, cemented by the same substance, with oxide of tin and copper pyrites in the crevices. A few large pebbles were composed of rich tinstone, but in general, the pebbles were wholly destitute of tin. Must we not suppose that these pebbles, however they came there, were formed previously to the tin? So numerous and various were the crystals of tin in this lode, that Mr. Phillips told me that, of those which he has engraved in his paper on the oxide of tin, he had obtained from this mine alone, a greater variety than from all the other mines in Cornwall.

Their veinstone is generally quartz. In some lodes, as in Huel Gorland, and Huel Unity, it is fluor.* In Dolcoath, Treskirby, and Huel Alfred, quartz and fluor are mixed. In some of the lodes of the United mines, and Huel Virgin, it is capel.† In Huel Squire, and in others of the United mines lodes, it is chlorite. In Chacewater it is hornstone and porphyry. In West Huel Unity, it is, for a short space, chalcedony. Those lodes are considered the most promising, which are composed on the back, or not far below the surface, of a rusty iron ore called gossan, either mixed with the usual veinstone, as in Huel Gorland and Huel Virgin, or being itself the veinstone, as in Cook's Kitchen.‡ Sometimes blackjack, or blende, is closely connected with the copper ore, as in Baldue, Nangiles, Huel Ann, &c: and it is considered a favorable symptom to find, on the back, tin ore, as in Huel Virgin; lead ore, as in Huel Alfred; or pyrites, as in Crenver.

Copper lodes of this class are considered very large, if they are six feet wide. Cook's Kitchen great lode is twelve feet, and West Huel Virgin

* The fluor spar occurs partially when the lode is in the slate; but more generally when it is in the granite.

† See the veinstones of the tin lodes.

‡ Gossan is found at all depths in the lodes, and is generally supposed to indicate a course of ore under it. In St. Agnes, however, there are numerous gossan lodes in which scarcely any copper has yet appeared.

lode nine feet; but the average width is not more than three feet.

The direction of most of these lodes is south of east, and north of west, perhaps 10°. on an average. In Penberthy Crofts, West Huel Fortune, Huel Alfred, &c., they run nearly east and west. In many other mines, as Poldice, Huel Fanny, Cook's Kitchen, &c., they run from 5°. to 20°. north of east, and south of west.*

The principal east and west copper lodes are,

1. The old lode in the United mines, which has been traced from a part of the parish of Camborne, through Carn-kye, to the mine of Baldue, a distance of seven miles. No other lode has been traced so far.

2. Huel Fortune and Huel Virgin lode, which has been seen for almost three miles in length, from the eastern part of Huel Fortune, to the top of Carn-marth Hill.

3. Huel Damsel and Huel Maid lode; two miles.

4. Huel Gorland, Huel Unity, and Creegbraws lode; two miles.

* Dr. Berger observes that the French used to call veins pointing E. S. E. and W. N. W. "filons du matin." The Cornish miners have carried this idea much farther. They call veins whose direction is due east and west, six o'clock veins; and the north and south veins, twelve o'clock veins: the veins, therefore, which run fifteen degrees N. of E. and S. of W. are five o'clock veins; and those which run fifteen degrees S. of E. and N. of W. seven o'clock veins: those which point N. E. and S. W. are three o'clock veins: and those which point S. E. and N. W. are nine o'clock veins. The same mode of describing the direction of veins appears to obtain at Freyburg.

5. The lode of Huel Nancy, Camborn-vean, Huel Gons, Straypark, Dolcoath, and Cook's Kitchen; a mile and half.*

6. Huel Towan lode; a mile and half.

7. The lode of Binner Downs, Huel Sarah, Huel Abraham, Oatfield, Crenver, and Trenoweth; two miles.

8. West Huel Fortune, Kestal, and Penberthy Crofts lode; three miles.

9. Huel Alfred lode; one mile.

The underlie of the copper lodes is various. In a line drawn from either Huel Fortune, or the United Mines, to Huel Alfred, they generally underlie northwards; † which, indeed, is the direction of the underlie of a very large majority of all the copper lodes.

The lodes on another line, south of the last, extending from Trenoweth, through Huel Abraham, Godolphin, &c. to West Huel Fortune, generally underlie southwards ‡. One of the lodes of Huel Fanny underlies north to the depth of 70 fathoms: below this depth it

* This lode is so disordered by cross courses at Cook's Kitchen, as not to be accurately traced further eastward. Many miners, however, consider it as the same lode that passes through Huel Fanny, Huel Druid, and Huel Sparnon, from whence its course is through Carnmarth Hill to Huel Damsel, Carrarach, and Huel Maid. This would be nearly six miles.

† In this line there are exceptions in Huel Sparnon, Cook's Kitchen, Dolcoath, Herland, Huel Carpenter, &c.

‡ There are a few exceptions on this line, but they are not so numerous as on the other.

underlies south. The lode of Huel Fortune also changes the direction of its underlie, at the depth of about 40 fathoms. The greatest underlie I have heard of is in Huel Squire, where the flat lode underlies eight feet per fathom. The average underlie is about two feet.

In Cook's Kitchen there are two intersections of copper lodes underlying in different directions. Those which have a northern underlie are traversed by those which underlie southwards: (fig. 16:) the latter are therefore, probably, more recent than the former.*

It has been shewn that the east and west copper lodes always traverse tin lodes, from which we may infer that they are the most recent of the both; and as the oldest east and west copper lodes are traversed by contra lodes, cross courses, cross flukans, and slides, they are probably more ancient than any of these.

1. By contra lodes †; as at Huel Alfred ‡, (fig. 17,) Mellanoweth, Huel Neptune, Huel Clowance, Godolphin, (fig. 18,) &c.

* It would be going too far to make a new class, with only two instances; especially as all those veins are traversed by cross courses.

† I do not mention the particulars of any of these intersections, unless they are worthy of notice on their own account. Crenver seems to present an exception to the general rule, as the contra lode in that mine, on meeting the great lode, is carried 70 fathoms in the direction of the latter: it then resumes its old direction.

‡ Here the contra lode intersects the great lode, and carries it in its own direction for 80 fathoms: the great lode then separates and resumes its former direction. The lodes may be easily distinguished when together.

2. By cross courses; as at the United Mines, Huel Jewel*, Cook's Kitchen†, Gunnis Lake‡, North Downs, &c. Intersections of this kind are so numerous that it is almost unnecessary to select particular instances.

3. By cross flukans; as at Huel Squire§ (fig. 7), Tingtang (fig. 11), Huel Unity, Huel Damsel, Huel Friendship, &c.

4. By slides; as at Treskirby (fig. 15), Huel Squire ||, Herland, Huel Friendship, &c.

In many copper mines, particularly the United Mines, the lodes have been found to be richest on approaching the cross courses, on both sides: but in some other mines, the lodes have been rich on one side of the cross courses; but barren on the other. The lodes of Huel

* The lodes of Huel Jewel are traversed by the great cross course, which is supposed to extend from the Bristol to the St. George's Channel, and heaved to the right, about 70 fathoms.

† The mines of Dolcoath and Cook's Kitchen are divided by a cross course, and the lodes are heaved to the right 50 fathoms.

The intersection of Dunkin's lode in Cook's Kitchen, by the little cross course, is singular. At the depth of 25 fathoms, the lode is not heaved at all: at 54 fathoms deep, it is heaved five fathoms; at 72 fathoms deep, six fathoms; and at 105 fathoms deep, 12 fathoms: all to the right.

‡ In this mine another curious shift occurs. At the depth of 70 fathoms, the lode is heaved 15 feet to the left; and at ten fathoms deeper, it is heaved 15 feet to the right.

§ Pearce's lode in Huel Squire, on meeting with a small cross flukan, is, at the depth of 26 fathoms, heaved eight fathoms to the right: but at 20 fathoms deeper, the heave is only three feet.

|| Here the slides underlie N. E. very rapidly, and throw down the lodes; but at the same time, they enrich or feed them, as the miners express it; the lodes being richest when near to the slides.

Jewel and Relistian were rich on the eastern side of the cross courses; but on the western side they were entirely unproductive. Is it not probable from these facts, that, in some cases, although the east and west veins were formed previous to the cross courses, the metallic ores in those veins were formed afterwards?

The junction of two copper lodes longitudinally, where there is no apparent intersection, is very common, particularly in some of the Gwenap mines. When the lodes are nearly of the same kind, in point of composition, and underlie towards the same point, the result is generally a great enlargement of the lodes, and a rich course of ore, even when both the lodes were previously barren: * but if the lodes are of different kinds, or underlie in an opposite direction, the result is quite opposite. Lodes meeting in this way, and shewing no kind of intersection, may be supposed to be of the same age: (fig. 19).

In several of the copper mines, there are some lodes of which no trace is to be found at, or near, the surface; but they are discovered either in the adit, or in some deeper level, and on being traced, are found to proceed downwards from some other lode. In Treskirby two of

* Huel Unity and Nangiles are exceptions to this remark. In these mines a junction of lodes longitudinally is rarely productive of riches; but generally the contrary

these lodes fall off from the old south lode, and in their downward course they unite: (fig. 15). In the United Mines several lodes fall off from Cupboard lode. In Tincroft and Cook's Kitchen also, lodes have been found under similar circumstances*: (fig. 16).

When copper lodes, from a state of poverty, become either gradually or suddenly rich, the change is generally rather in the qualities, than in the constituent parts, of their veinstones: as, from hard quartz or capel, to quartz in a state of decomposition, called by the miners *sugary spar;* or to soft chlorite, which they call *peach.* Another frequent change is from a very solid compact lode, to what the miners call a *hollow* lode, abounding in cavities. Sometimes the lode becomes greatly enlarged.

Most copper lodes are accompanied by small flukan veins; (termed by the miners, the flukan of the lodes). These are probably more recent than any other parts of those lodes, and almost deserve a separate place as veins within veins. They appear sometimes on one, and at others, on both sides of the lodes, and in some cases in the middle. They frequently cross from one

* Mr. Phillips (Geol. Trans. Vol. 2.) appropriately calls these "*offsets.*" I have endeavoured to keep as clear as possible of his paper; but for the sake of connexion I have been obliged to make a few remarks similar to his. I have, however, omitted many circumstances relative to veins, which are not immediately connected with their age, because they have been mentioned in previous publications.

side to the other. In some instances they have separated from the lode, and, in a few fathoms, have joined it again.*

The veins which have produced tin in the upper part, and copper below, probably belong, some to the class of tin lodes, and others to that of copper lodes †. Only one instance has been known in Cornwall of a lode producing copper above, and tin below, exclusively, viz. the great lode in Cook's Kitchen ‡. In Tincroft and Dolcoath, tin is found connected with copper in the lodes, in the deepest parts of those mines. In some copper lodes, tin is so plentiful in some parts, as to give them, for a short space, the appearance of tin lodes.

* I apprehend these are what Werner calls the saalbande. They are, perhaps, the result of fissures in the lodes, occasioned by the consolidation, and consequent contraction, of their parts. In most of the mines of Gwenap, and in many others, they are considered favourable to copper. They are sometimes attendant on tin lodes, but not so generally.

† The great capel lode in West Huel Virgin is called a tin lode, and is traversed by Tregoning's copper lode; but in its downward course the tin declined, and it became rich in copper. On the other hand, Cargruel lode, in the United Mines, which produced tin in the upper part, and copper below, traverses Rapsey copper lode.

‡ This lode is 12 feet wide, runs east and west, and underlies south. Toy's lode, two feet wide, has the same direction, but underlies north. At the depth of 105 fathoms, the great lode was very rich in copper: here Toy's lode fell in with it, and *cut out* nearly all the copper. Toy's lode is traversed by the great lode, and thrown down 18 fathoms, (Fig. 16.): in this space, the latter contained both tin and copper. After Toy's lode separated from it, the great lode continued its course to the depth of nearly 190 fathoms, as a tin lode. It produced no tin worthy of notice before the intersection, and scarcely any copper afterwards.

It appears, from the result of long experience, that little is to be expected from copper lodes which may be discovered in what may be strictly called a tin country: the copper-ore is, in such cases, generally found in short bunches, which do not pay the expence of searching for them. This may be proved by a reference to the parishes of Wendron, St. Agnes, St. Just, the southern part of Breage, and the neighbourhood of Polgooth, and Great Hewas mines.*

From the frequent junctions of the granite and slate in the mining districts of Cornwall, many of the copper mines are situated on, or near, the lines of junction. Some of the most productive mines are directly on the lines, viz. Huel Unity, Treskirby, Dolcoath, Cook's Kitchen, &c. In Treskirby, Huel Gorland, Tresavean, and Nangiles †, the lodes improved on entering the granite from the slate. In Huel Unity, Cook's Kitchen, and Dolcoath, scarcely any alteration was perceptible. ‡ In Botallack, Huel Cock, and other mines in St. Just, the copper lodes are more productive in the slate than in the granite, but they are richest on the

* Huel Towan, which may be cited as an exception to this rule, is not in the tin district of St. Agnes. In Huel Unity and Poldice, there are very productive tin lodes; but they are in a copper country.

† Here the lode, which, in the slate, was principally quartz, became, in the granite, a flukan lode.

‡ In all these mines, a much larger quantity of ore has been raised in the slate than in the granite country, because the ore has extended much further in the lodes when in the slate.

line of junction, especially when one wall is granite, and the other, slate. This is also the case in Treskirby, and was formerly so in Carrarach. On the whole, however, the slate country may be considered more favorable to copper, than the granite. Several rich and extensive copper mines have been wholly in slate; as Huel Towan, Huel Alfred, Herland, United Mines, Huel Virgin, Crennis, &c.; but I apprehend there is not one which is wholly confined to granite.*

The following minerals have been found in east and west copper lodes. Stalactitic, botryoidal, and investing chalcedony: stalactitic, swimming, and cubic quartz; and rounded shist pebbles; all in Huel Alfred: red jasper, in West Huel Unity: sulphat of barytes in the United Mines†: wolfram and oxide of uranium, in Tincroft, Tolcarne, and Gunnis Lake‡: sulphate of lead in Mellenoweth §: petroleum in

* Huel Damsel, Huel Jewel, Tresavean, and Huel Gorland, are not wholly in the granite. The slate appears in the eastern part of all those mines.

† It was found in the great south lode, from the depth of 100 to 160 fathoms, and generally preceded a rich course of ore.

‡ The uranite is in four-sided laminæ. It has been found from 28 to 69 fathoms deep, at the point where an east and west copper lode is intersected by a contra lode. The finest specimens were found in the deepest part.

§ The gossan, or top of the copper lode, was full of crystals of this substance, of which I have seen the quadrangular prism, with its pyramid; the rhomboidal prism, and the octahedron, with several modifications.

Treskirby, Huel Unity, and Carrarach: arseniate of cobalt, in Dolcoath: grey silver ore and native silver, in Huel Ann *: kupfer nickel, in Pengilly, in the parish of St. Ewe. The arseniate of copper was found in Huel Unity, where the lode was between the granite and the slate. The arseniate of lead occurred just at the junction of a contra lode, with an east and west lode.

FOURTH CLASS. *The Contra Copper Lodes.* The contents of these lodes are nearly the same as those of the east and west copper lodes, the only difference lies in their having more flukan in their composition.

They are in general wider than the east and west lodes. Huel Neptune lode is twelve feet wide. Huel Alfred, nine feet; Crennis, ten to fifteen feet. The average width may be stated at four feet.

Their direction is in general from 30°. to 45°. south of east, and north of west: some however run in a directly opposite direction, viz. north-east, and south-west; as in Huel Gorland, United Mines, Huel Friendship, Penberthy Crofts, &c. †

* These were found in a small vein, having distinct quartz walls, in the middle of the copper lode.

† The miners give the name of *contra* to every lode which is much out of an east and west direction, and crosses the lodes which run east and west: but I am not aware that east and west lodes are traversed by any contra lodes which are not at least 30 degrees from those points.

Their underlie is much the same as that of the other copper lodes: about two feet per fathom on an average.

They are very few in number, compared with the east and west lodes; and none of them have been traced so far. The Herland contra has been traced three miles, and the Huel Gorland great gossan, about a mile. I believe no others have been traced farther.

They are as productive of copper as any other lodes: of this the contra lodes of Huel Alfred, Crennis, and Huel Neptune, furnish sufficient proof.

They (as well as the east and west lodes) are usually accompanied by small flukan veins, which are probably more recent than the other parts of the lodes.*

No instance has occurred in which contra copper lodes are traversed by any of the veins which have been already described: they are traversed however by veins of other descriptions, viz.

1. By cross courses: as in the United Mines †, Herland ‡, &c.

* In Huel Alfred a flukan always accompanied the contra lode, in some parts on one side; and in others, on the other. When it was on the south west, or lower side, the lode was much richer than when it was on the opposite side: it at length separated from the lode, whose riches immediately began to decline: in the deepest level, it was 15 feet from the lode, and here the barrenness of the lode obliged the adventurers to abandon the concern,

2. By cross flukans: as in Huel Gorland, Huel Fanny §, Godolphin, Huel Alfred (fig. 17), Crennis, Huel Treasure, &c.

3. By slides, as in Huel Neptune, Huel Friendship, &c.

The beautiful specimens of arseniate of iron which were so plentiful some years ago, were found in a contra lode, viz. Huel Gorland great gossan: and in Crennis lode have been found some specimens of fahlerz.

Fifth Class. *Cross Courses.* These veins are sometimes composed wholly of quartz, but they usually contain, besides quartz, a large portion of flukan, and in some cases the quartz appears on one side of the vein, and the flukan on the other: when this is the case, the flukan is probably the most recent part of the vein. Many cross courses have a portion of gossan in their composition: these are called cross gossans.

The width of these veins is greater, and more variable, than that of the tin and copper lodes. One of the cross courses in Huel Vor is 36, and

† Here there are two contra lodes, called Cargruel lode, and Trelease's contra, both of which are traversed by a cross course in one part of the mine, and in another part by a cross flukan: by the former they are heaved 12 feet; by the latter 16 fathoms.

‡ Here the cross course carried the contra lode with it for about eight fathoms. In this space the two veins appeared as one, and the whole was rich in copper ore.

§ Here the lode is not heaved, but appears bent on each side of the flukan.

another, 20 feet: the Huel Peever cross course is 20, and that of Carrarach, 12 feet. Their average width is at least 6 feet.

Their direction is sometimes north and south: sometimes west of south, and east of north, but most frequently west of north, and east of south; seldom exceeding 20°. on either side.

Their underlie is as various as their direction; but it appears that most of those which point east of north, underlie towards the west; as at Penberthy Crofts, Huel Alfred, Weeth, and Huel Carpenter; and the greatest part of those which point west of north, underlie towards the east: as at Huel Vor, Huel Squire, North Sealhole, United Mines, &c.

These veins are sometimes the cause of incalculable trouble and expence to the miner, by shifting the lodes from their usual course, by deranging their contents, and oftentimes by cutting out all their riches. On the other hand they are sometimes advantageous, as that part of them which consists of flukan is quite impervious to water.

The principal cross courses in Cornwall have been traced from the shore of the Bristol Channel, near Porth Towan, through St. Agnes and Illogan Parishes to Huel Peever. In the cliff they are at some distance from each other, and between Porth Towan and Huel Peever, they traverse all the veins in their way, and heave

them, the eastern cross course 54, and the western, 18 fathoms. In the southern part of Huel Peever they unite, and form one course of four fathoms wide, which, after heaving the lodes of Huel Jewel about 70 fathoms, continues its way to some confused ground near Huel Damsel, south of which it heaves the lodes only 16 fathoms. It has been traced nearly eight miles.*

The other cross courses most worthy of notice are Tiddy's great cross course in the United Mines, Paul's cross course in Huel Virgin, the cross courses in Mellanear, Huel Alfred, Weeth, Relistian, Huel Sarah, Huel Vor, Cook's Kitchen, &c. of these the Huel Vor cross courses have been traced two, and that of Relistian, three miles.

To the class of cross courses probably belong the large north and south veins which traverse the whole of the extensive parish of St. Just. They are called by the miners "guides," because they suppose that by following those veins, they will be conducted to the tin lodes; but they may with more propriety be termed iron lodes, as they contain, besides quartz and clay, brown

* Dr. Berger says it terminates at Pedn Boar point: (Geol. Trans. vol. i. page 165.) but its termination has never been discovered, and for the space of five miles before it reaches the southern coast, it has not been traced at all, as, at a short distance from Huel Squire, it leaves the mining district: but a line drawn from Huel Peever, through its last visible point, would find its termination at, or near, Swan pool, a mile west of Falmouth.

iron-stone, specular iron ore, brown hæmatite, &c. Two of them have been traced three, and another, five miles. When they intersect the lodes, they generally carry them several fathoms in their own direction, before a separation takes place. In such cases the lodes are frequently much improved. In two instances which occurred in Botallack and Parknoweth, very rich courses of tin have been the result of such intersections.*

It has been shewn that cross courses traverse all the true veins which have been already described: it remains to be shewn that they are traversed by other veins.

1. By the more recent copper lodes: as at Penberthy Crofts, Huel Alfred, (fig. 17,) Huel Smart, and the Weeth. †

2. By cross flukans: as in the valley north of Huel Damsel ‡, and at Huel Alfred.

* I have been told that one of those veins is twice shifted from its usual course by tin lodes; but as the mines in which those shifts are said to have occurred are not now at work, it cannot be ascertained whether the statement is correct; and as the accounts which I have obtained are various and contradictory, I am not at all satisfied of their occurrence, especially as in every other instance where those veins and the tin lodes meet, the latter are traversed by the iron lodes. The mode of working the St. Just mines renders it, in most cases, difficult to ascertain satisfactorily the result of the intersection of different veins.

† This is a singular intersection. Two cross courses are traversed by the same east and west lode. One, whose direction is ten degrees west of north, and east of south, is heaved three fathoms to the left: the other, which points about ten degrees east of north, is heaved three fathoms to the right. (Fig. 12.)

‡ This valley is intersected by the large cross course which is

3. By slides: as at the Garres*, Polgooth†, and Herland.

It is not at all strange that so few instances have been met with of the intersection of cross courses, by cross flukans, and slides; for however frequently these may occur, they are not likely to be discovered, except in adits which may be driven in the same direction; or unless they happen just at their intersection of metalliferous veins; for, in general, those cross veins have nothing valuable in themselves, to make them worthy of pursuit.‡

supposed to run from sea to sea, and this cross course is traversed completely, by a cross flukan. The country in a part of this valley bears the marks of convulsion, being in great disorder and confusion. The cross course evidently partakes of this disorder, but the flukan appears to bear no marks of it. If therefore there had been no intersection, there would be no difficulty in ascertaining the comparative age of those two veins. The Weeth also furnishes an instance in proof of the more recent formation of cross flukans: the north copper lode traverses two cross courses, and is itself traversed by a cross flukan.

* This is a lead-mine near Truro, the lead being found in a cross course, which is intersected by two slides, by each of which the lead vein is thrown up six fathoms.

† Here Screed's tin lode, which is a cross course, is heaved by a slide. —I am aware that there are two instances in Huel Peever, in which the slides are traversed by the cross courses. In these cases, it is probable that the slides are the oldest: but I believe the slides are in general the most recent; 1, because of their composition, which is wholly clay: 2, because some of the east and west lodes which traverse cross courses, are found to be traversed by slides.

‡ It is much to be desired that a plan and a section of every mine should be made, and exposed to view in the account house. The utility of this is strikingly proved by the circumstances which occurred in Dolcoath. After cutting through the cross course by which the great lode was traversed, a lode was discovered on the opposite side, about three fathoms to the right, which was supposed to be the

Cross courses are in general unproductive either of tin or copper; but some rare instances have occurred in which both these metals have been found in them. In Polgooth, Screed's lode, which is a cross course, was rich in tin. In Huel Music, two small gossan cross courses have produced some of the richest copper ore in Cornwall. In Huel Jubilee also the copper lode is a cross course. It, however, frequently happens that cross courses, on intersecting rich copper or tin lodes, partake of their riches for a short space. In Huel Peever, the cross course was rich in tin several feet north of the point at which it intersected the tin lode; and in Treskirby, Kinsman's cross course was rich in copper for about ten feet north of its intersection of a copper lode; but on the southern part they were quite barren.

Lead is the principal metal found in cross courses, in Cornwall: but at present there are very few lead mines wrought. Pentire glaze * near Padstow, and Huel Golding in Perranzabuloe, are the principal mines in which the lead occurs in cross courses. †

great lode, and was pursued as such, until a correct plan of the mine was made: it then appeared probable, from the direction of the lodes, and other circumstances, that the newly discovered lode was not the great lode. The latter was afterwards discovered at the distance of 50 fathoms. (Fig. 9.)

* This mine has lately produced the finest cabinet specimens of carbonate of lead ever known in Cornwall, or perhaps in Great Britain.

† Dr. Borlase in his Nat. Hist. of Cornwall, observes that the lead veins of Cornwall generally run east and west. This is not correct, for, except in one instance, the lead veins are cross courses.

The following substances also, have been found in cross courses, viz. Arseniate of cobalt, at Huel Trugo and Huel Sparnon.* Sulphuret of antimony, and the triple sulphuret of antimony, lead, and copper; at Huel Boys †. Native silver, and several ores of that metal, at Huel Mexico, Herland, and Huel Basset. Petroleum, at Huel Jewel.

SIXTH CLASS. *The more recent Copper Lodes.* This class will comprize the east and west, and also the contra lodes, which have been found to traverse not only other copper lodes, but cross courses also. They are not numerous, but they may be seen at Penberthy Crofts, Huel Alfred (fig. 17), Huel Smart, and the Weeth (fig. 12).

There is nothing in their size, direction, or underlie, which distinguishes them from the copper lodes which have been already described; but with respect to their composition, they must be styled flukan lodes, having more clay in them, than is usually seen in the cross courses.

In this class must probably be placed the lead veins which have been lately discovered

* In both these mines the cobalt was found in some parts of the cross courses in regular veins; and in others, in small bunches. In Huel Sparnon, one solid mass was brought to the surface, which weighed 1333 pounds.

† The vein is about one foot wide, and has been wrought to the depth of 86 fathoms. It has yielded as much as 100 tons in a year of regulus of antimony, containing eight parts in twenty of pure antimony; but it does not now produce half that quantity.

in the parish of Newlyn, by Sir Christopher Hawkins, in draining a marsh. They are about two feet wide, and run nearly east and west: a direction contrary to that of almost all the other lead veins which have been hitherto discovered in Cornwall. Besides the lead, and a little quartz, they consist entirely of clay. Neither copper nor tin has been seen in them. Those veins are far richer than any north and south veins in which lead has yet been found. The lead yields about sixty ounces of silver per ton.*

The veins of this class are traversed

1. By cross flukans: as at Penberthy Crofts, Huel Alfred (fig. 17), and the Weeth (fig. 12).

2. By slides: as at Penberthy Crofts.

SEVENTH CLASS. *The Cross Flukans:* or cross courses which are composed wholly of clay†. They vary in width, from the smallest imaginable size to nine feet, but their average width is not so great as that of the cross courses, as most of them are less than one foot wide. However small they may be, no water can percolate through them.

Their general direction is nearly north and south: their underlie is much the same as that

* This paragraph has been added since the reading of the paper, as those veins were then scarcely known.

† The miners give to cross flukans in general, the common name of cross courses, unless they are very small: they are then termed simply "flukans."

of the cross courses: generally towards the east.

The results of the intersection of tin and copper lodes by cross flukans, are nearly the same as those which attend cross courses. Most of the heaves by these veins are to the right.

The arseniate of lead was found at Huel Unity, just at the point where a cross flukan insersected a copper lode.

The cross flukans traverse every kind of vein but the slide; and Herland presents the only instance which I have been able to find, of the intersection of those two veins. In that mine a slide, of the width of three inches, traverses several cross flukans.

When a miner, working on a lode, meets with a cross course or cross flukan, he generally cuts through it*. If the lode is heaved, he endeavours to ascertain where he will probably find it on the other side; 1, from its having been discovered in other levels in the same mine; 2, from the manner in which other lodes near it, having the same direction, are shifted by the same cross vein; 3, by searching for some of the component parts of the lode on one side of

* Unless he wishes to let it remain for the purpose of preventing an influx of water from the other side. In some cases, where a lode has been poor, the adventurers, on meeting with a cross course, have, in despair, abandoned the concern; but the previous poverty of a lode ought, in all cases, to be a strong reason for cutting through the cross course.

the cross vein; 4, by observing the direction in which other lodes in the neighbourhood are heaved by other cross veins. If his judgment can derive no assistance from either of those circumstances, he will naturally drive at first on the right hand, because in most cases, lodes are heaved to the right: if, after driving a few feet, the lode is not discovered, he will turn to the left, and drive the same distance: if this is unsuccessful, he will return to the right, and again to the left; and thus he will continue until he has discovered the lode.

It has been laid down as a rule,* that when a lode is heaved, the part broken off is to be found on the side where its junction with the cross vein makes the smallest angle (fig. 13); but nothing is more uncertain than this. In Huel Vor, all the lodes are found on the side of the largest angle (as in fig. 14). In the United Mines, all the lodes are heaved to the right; and as their direction is different, some are found on the side of the smaller, and others on that of the larger angle of intersection. This is also the case in Huel Unity, and Huel Gorland, where all the lodes are heaved to the left. In Huel Squire there are some heaves to the right hand, and others to the left; but most on the side of the larger angle (fig. 7).†

* Pryce, page 99.

† Tingtang furnishes an instance of four heaves, by three cross flukans, and a cross course, within a very short space; all to the

Neither does the direction of the heave appear to depend on the underlie of the lodes, or the cross courses. In Huel Squire, Andrew's flukan underlies towards the east, and all the lodes towards the north, yet they are all heaved to the left: the same circumstance occurs in Huel Unity. Odgers's and Morcom's flukans in Huel Squire, underlie towards the east, and the lodes towards the north; but the lodes are heaved to the right. In Cook's Kitchen, three lodes underlie northward, and two towards the south: the great cross course underlies to the east, and the little cross course to the west: yet all the lodes are heaved to the right by both the cross courses.

The distance to which one part of a lode is shifted from the other, by a cross course, or cross flukan, does not at all depend on the size of the cross vein.* In Huel Virgin, a cross course, two feet wide, heaves the lodes nearly six fathoms; and in Huel Peever, another of the same width heaves the lode 18 fathoms: whilst in Huel Sparnon, a cross course of the width of eight feet, heaves the lodes only two fathoms. In like manner, a cross flukan in Huel Unity, 18 inches wide, heaves the lodes five fathoms:

right; but as the direction of the flukans is different, the angles of the heaves are also different, (fig. 11.)

* Pryce has asserted the contrary, with respect to slides and copper lodes, or gossans, as he calls them; (page 106, 107,) but I am persuaded, incorrectly.

another in Huel Squire, of the width of two feet, heaves the lodes 19 fathoms: and a very small one in Huel Daniel heaves the lodes 14 fathoms: Whilst in the United Mines, a flukan above two feet wide, heaves the lodes only one fathom.*

It will doubtless have been observed, in the description of the copper and tin lodes, that most of those lodes, on meeting with cross courses, or cross flukans, are shifted in such a manner as to be found by turning to the right hand. Left handed shifts are comparatively few. From the appearance of many of the lodes, and the alteration in their general direction, on the western side of the cross courses; and from some of the cross courses being rich in copper and tin for several feet north of their intersection of copper and tin lodes; I conclude that, of the lodes which appear to be heaved to the right hand, the western branches have been shifted towards the north. Whether the eastern branches of the lodes which are heaved to the left, have been also shifted towards the north, there are not the same grounds of deciding. The probable cause of these shifts, and the mode in which they have been effected,

* The lode of Crennis is stated to be heaved 200 fathoms, by a flukan of eighteen inches wide; but this immense distance makes it probable that what are supposed to be two branches of the same lode, are really two distinct lodes; especially as there are no corroborative circumstances to make such a fact probable.

cannot be discussed without involving theories which have little immediate connexion with the relative age of veins.

EIGHTH CLASS. *The Slides:* probably the last class of true veins; being found to traverse veins of every other kind.* They are composed wholly of clay, which is generally of a more slimy nature than is often found in other veins.

They run in all directions; but their general direction is nearly parallel with that of the tin and copper lodes. Instead therefore, of heaving them longitudinally, as the cross veins do, they either throw them down, or throw them up: the former when they underlie in the same direction as the lodes: the latter, when in an opposite direction.†

These veins are generally very small: seldom more than one foot wide; and they usually underlie very fast, which indeed is probably the reason of their being called *slides:* or perhaps because, when they underlie in the same direction as the lodes, the latter, on meeting them, appear to *slide* downwards.

There are slides in Treskirby, Huel Squire, Huel Vor, Huel Friendship, Huel Neptune, Gwallan, &c.

* With the exceptions in Huel Peever.

† This is stated in general; but there are some exceptions. In the Garres, where two slides underlie in nearly the same direction as the lead lode, the latter is thrown up by both of them.

The result of the meeting of other veins with slides has been already shewn in describing those veins, and need not be repeated.

I believe I have now described all the true veins which are found in Cornwall; but in order to exhibit, at one view, the intersections of the different veins, a few instances may be separately repeated.

In Huel Trevaunance, a tin lode is traversed by two other tin lodes: all these are traversed by several east and west copper lodes; and a slide traverses the whole.

In Huel Alfred, the east and west copper lode is traversed by a cross course: both are traversed by a recent copper lode; and a cross flukan traverses them all (fig. 17).

In Herland, the east and west copper lodes are traversed by a contra lode: these are traversed by several cross courses and cross flukans; and all of them are traversed by a slide.

In the Weeth, the south copper lode is traversed by two cross courses, which are in turn traversed by the north copper lode; and both the lodes are traversed by a cross flukan (fig. 12).

In describing the contemporaneous veins, some were mentioned as occurring in the veinstones of other veins. There are also metallic veins which may be denominated veins within veins.

1. SILVER. In the copper lode of Huel Ann, there occurred a distinct vein of black and grey

silver ore, with native silver, from two to five inches wide, with a wall of quartz on each side: It was however very short both in length and depth.

2. Tin. The wood-like oxide of tin is frequently found in veins, both in quartz and in tinstone, with which they have the strongest appearance of being contemporaneous. The common tinstone also often occurs in veins, crossing the veinstones of the lodes. The cabinet of the Society contains a fine specimen of this kind, as well as of the silver vein.

3. Copper. The green carbonate of copper is found in veins, in quartz, which is the veinstone of the lodes, in Huel Carpenter, Huel Neptune, &c. The blue carbonate occurs in the same way in Tingtang; and the arseniate, particularly that variety of it which is called wood-copper, in Huel Unity. Native copper was found in veins, in the quartz of the lode, at Godolphin, and sulphuret of copper, in the same manner, at Huel Jubilee. I have also seen veins of brick-coloured oxide of copper in the lode of Huel Damsel. Those veins have, in most cases, the appearance of a formation posterior to that of the containing veinstones.

4. Iron. Veins of the woodlike oxide of iron are occasionally found in brown iron-stone, and appear to be contemporaneous with it. At Botallack and Boscagel-downs, veins of fibrous

oxide of iron are very common in the quartz of the lodes, and veins of carbonate of iron at Huel Jubilee.

5. BISMUTH. The native bismuth which was, some years ago, found in one of the lodes of Botallack, occurred in minute veins, in coarse red jasper.

With respect to the relative ages of the several substances contained in the true veins of Cornwall, it is not often that we have many circumstances to guide us, on which we can safely depend. In general, an ochreous oxide of iron (gossan) is found in the upper part of the copper lodes, to which sulphuret of iron (mundic) frequently succeeds: below this, the miners confidently expect to find copper ore. If, however, the lode becomes barren in its downward course, the gossan sometimes appears again, under the barren part, and is introductory to another bunch of copper ore below it.

In the lodes of Herland and Huel Carpenter, carbonate of copper, and in that of Huel Unity, arseniate of copper, has been found on quartz, of whose crystals they have received the impression. The latter mine has also produced arseniate of lead, of which a mass of minute crystals appears to invest crystals of quartz. From Botallack lodes I have seen brown hæmatite and iron pyrites investing crystals of quartz, and also quartz which has received the impres-

sion of the hæmatite. In all such cases, where one substance has the form in which it is generally found, and the other a form in which it rarely, if ever, occurs separately, it may be concluded that the latter is the most recent.

The principle on which I have hitherto proceeded in order to ascertain the relative ages of the several classes of true veins, has been entirely that of intersection; and I have mentioned few, if any instances, in which it may not be satisfactorily proved, both from a similarity of size, appearance, and contents, in the broken parts of the lodes; and from the shifting of other lodes in the same way, by the same intersecting veins; that the veins which are described as being shifted, and which are found on the opposite sides of an intersecting vein, are really broken parts of the same vein, and not different veins which terminate where they appear to be broken off. But I think another principle may be deduced from the whole of the preceding remarks: viz. that veins which contain the greatest quantity of flukan or clay, are generally found to traverse those which contain a less quantity, or none at all of that substance. On this principle, the east and west veins, whose veinstones are quartz, shorl, chlorite, or a mixture of those minerals, with scarcely any clay in their composition, will be found the most ancient. These are the tin lodes. The east and

west veins, having veinstones of different kinds, and containing a small mixture of clay in them, come next. These are the oldest copper lodes. Then come the contra lodes, which contain more clay. Next, the cross courses, in which the quantity of clay is still larger. Then follow the more recent copper lodes, which have a still greater proportion of clay. After these, the flukan veins, and the slides, which are nearly all clay.

I have purposely abstained from speculating on the manner in which the contents of the veins were originally placed in the fissures which contain them. There is one point, however, to which I cannot help alluding, as it has been made to bear on different theories. It has been stated by some, that veins become smaller as they get deeper: others have asserted the contrary: but as far as the earth has been penetrated in this county, it appears evident that neither of these statements can be maintained as a general position. The lode of Huel Abraham, the deepest mine in Cornwall, is larger at the depth of 240 fathoms, than it was nearer the surface. In Dolcoath, the deepest mine next to Huel Abraham, the principal lode was largest at the depth of about 80 fathoms. The lode of Huel Alfred was much larger at the depth of 110 fathoms than at any less depth; but at 150 fathoms deep, it had considerably decreased in

size. The Huel Neptune lode, which was nine feet wide near the surface, is about the same width at the depth of 130 fathoms.

That part of Cornwall in which most of the veins which have been described are found, has generally been regarded as a primitive country, consisting for the most part of the oldest granite, and of primitive slate, or argillaceous schistus, now generally called clay-slate.

The claim of the granite which forms the chain extending from the Land's end to Brownwilly, to the name of primitive granite, has rarely, if ever, been seriously disputed. The supposition that Saint Michael's Mount is transition granite, rests entirely on the occurrence of granite veins which appear to be connected with the granitic mass, intersecting the slate. Perhaps, however, it will appear from the facts which have been mentioned respecting those veins, that, whatever may be *their* relative age, the mass of granite may still be of primary formation.

The claims of the clay-slate, however, have of late been disputed, and it has been called transition slate, and greywacke slate, by geologists whose authority certainly carries considerable weight: but by what rules are we to distinguish primitive, from transition slate? In its structure, the clay-slate of Cornwall appears, in general, perfectly homogeneous. It contains no im-

pressions of any kind. Some of the oldest metals have been found in it: viz. oxide of tin, wolfram, and mispickel: these have been discovered *in* the slate: and they have also been found, together with sulphuret of tin, native bismuth, and oxide of uranium, in the veins which intersect it. Some of the oldest minerals have also been found in it; viz. axinite, garnet, topaz, &c. Are not these some of the strongest marks of a primitive rock? Some specimens of it were sent by a member of our society to Werner, who recognised in them the clay slate of Saxony.

That greywacke exists, and abounds in some parts of Cornwall, will not be denied; but I apprehend it is not to be found, except in small and scattered portions, in that part in which nearly all the tin and copper mines are wrought. It appears to commence near Grampound, and to extend westward about three miles from Truro: how far southward, I have not been able to ascertain. Its extent northward, in mass, is probably not from Truro, but it is found in bunches as far as Padstow, and Tintagel Castle. Near the former place it is highly characterized; and at Tintagel, impressions have been found in it. The lead veins of the Garres, and those of Pentire glaze, and the vein of antimony at Huel Boys, are probably in greywacke; but I have never seen either copper or tin *in* greywacke, nor am I aware of any tin veins which intersect it.

It is worthy of observation, that the riches of the east and west lodes which are comprised in the great mass of tin and copper mines, appear to terminate with the clay slate formation eastward. If a line be drawn from the eastern parts of the mines of Nagiles or Baldue, to the eastern part of the parishes of St. Agnes or Perran, it will form the eastern boundary of the mines. If the lodes of those mines continue in the greywacke, they are generally divided into small branches; but this has not been ascertained, as its junction with the clay slate is so gradual, that the line of division can scarcely be discovered: it however gradually recedes from the clay-slate in character, as in distance; and between Truro and Grampound, its characters are very distinct. The clay-slate appears again near Grampound, and there also the lodes and the mines recur. One would therefore almost suppose that making of the clay-slate had taken place in the intermediate space, forming a kind of basin in which the greywacke had been subsequently deposited; and that the lodes of Great Heward Polgooth tin mines, and of Crennis, Huegent, and Huel Treasure copper mines, was a continuation of the lodes of the principal mines in the parishes of Redruth and Gwennap.

It will not be observed that the remarks which I have made respecting rock-veins are applicable, for the most part, only to those of

the western parts of Cornwall. There is a large extent of coast (principally clay-slate) open both to the Bristol and the British Channels, of which little notice is taken. In truth I have not been able to examine any part of the south coast, east of Falmouth Harbour; and very little of the north coast, east of Cligga point. Many veins therefore, different from those which are here noticed, may possibly remain for future description. But when it is considered that, with few exceptions, all the veins which have been described, occur in a tract not more than thirty miles long, and ten miles broad, on an average; I may safely repeat that, in all probability, no other district of equal size can compare with Cornwall in the number and variety of its mineral veins.

It is scarcely necessary, in conclusion, to apologise for the frequent use of the common terms of the miners. In a paper of this kind, it is almost impossible to substitute others for them. In strictness, most of them are inaccurate, especially as applied to the shifts of veins; as they describe the apparent, and not the real change which has taken place: but whilst we comprehend what is intended by them, we may talk, and write, of veins being *heaved, thrown up, thrown down, wrung up, cut out, &c.*, just as reasonably as we do of the rising, and setting, and course, of the sun.

Fig. 1. Sealhole.
Cross Section. N and S.

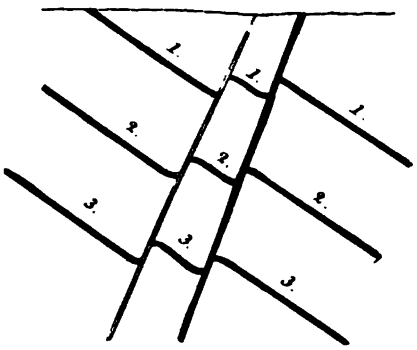


Fig. 2. Huel Peever.
Cross Section.

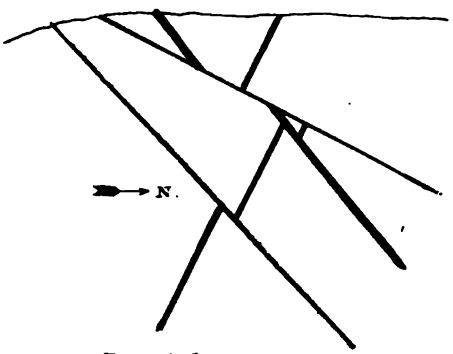


Fig. 3. Huel Peever.
Ground Plan.

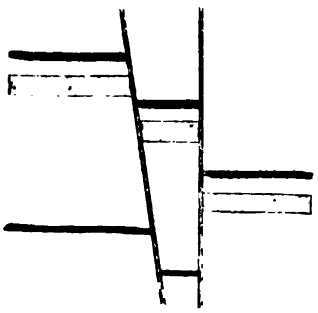


Fig. 6. North S
Ground Pla

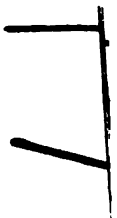
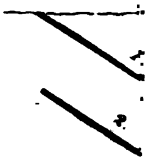


Fig.
Cro



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Observations on the Submersion of part of Mount's Bay; and on the Inundation of 'rine Sand on the north coast of Cornwall.

By HENRY BOASE, Esq.

TREASURER OF THE SOCIETY.

OUGH the labours of geologists are limited, ɜral, to the investigation of the formation, and law of the substances which com- ıe shell or crust of our Planet, yet it is ɔgether foreign to those studies, to ex- uch remarkable alterations of the surface, vidently not attributable to the slow ope- ɔf the ordinary course of natural causes, nain lasting memorials of a sudden over- occasioned by some violent shock of ding elements.

ıwall, being mostly of primitive structure, .sed considerably above the level of the ɔes not exhibit many instances of post n derangement. The two most remarka- the submersion of a considerable extent

of low woodland, now forming a part of the Mount's Bay;—and the inundation of sand, which buried a large tract of cultivated land bordering the sea coast, from St. Ives eastward to beyond Padstow, particularly in the parishes of Lelant, Phillack, Gwithian, Perranzabuloe, Crantock, and St. Enodock.

Of the time and manner of these catastrophes there is no record, a circumstance remarkable, if, as supposed by some, they happened after christianity prevailed, and monkish establishments were formed in this part of Great Britain. All the historians of this county, from Leland, Norden, and Carew, downward, have noticed the ancient tradition of St. Michael's Mount being formerly situate in a wood, several miles from the sea. They have also handed down as a concurrent tradition, according to Carew, who, treating of the ancient extent of the county, says, "The encroaching sea hath ravined from "it the whole country of Lionnesse, together "with divers other parcels of no little circuit: "and that such a Lionnesse there was, these "proofs are yet remaining. The space between "the Land's-end and the isles of Scilly, being "about thirty miles, to this day retaineth that "name, in cornish, *Lethowsow*, and carrieth an "equal depth of forty or sixty fathoms, (a thing "not usual in the sea's proper dominion,) save "that about midway, there lieth a rock, which

" at low water discovereth its head. They term " it the *Gulf*, suiting thereby the other name " of Scilla. Fishermen also casting their hooks " thereabouts, have drawn up pieces of doors " and windows." (Carew, p. 3.) To this, Dr. Borlase (Letters on the Scilly Islands) adds, " That there existed formerly such a country " as the Lionnesse, stretching from the Land's- " end to the Scilly Islands, is much talked of in " our parts. Some fishermen also have insisted, " that in the channel between the islands of " Scilly and the Land's-end, there are to be seen " tops of houses, and other remains of habita- " tations." Dr. Borlase, however, seemed desirous of shewing that he put no implicit faith in the story, by adding, " But I produce these ar- " guments only as proofs of the tradition, and " of the strong persuasion which from time " immemorial has prevailed among the inhabi- " tants of Cornwall, that such a country as Lion- " nesse once existed, but is now buried under " the sea." Though it must be acknowledged, that two pages after, the venerable and learned historian appears to credit the story, which then touched on a string that vibrated very powerfully on a favorite theory, viz. the rock idols, and rock sacrificial basins, of the Druids. " A " person taking a survey of the channel in the " year 1742, took one of his stations, as he told " me, on the Wolf-rock, where he observed a

" cavity, like a brewer's copper, with rubbish at
" the bottom, without being able to assign any
" cause for its coming there. This cavity could
" be no other than a rock basin; and conse-
" quently this rock is greatly sunk, being now
" entirely covered with the sea, at least nine
" hours in twelve."

Dr. Macculloch has abundantly proved that all the fancied statuary of the Druids, the hollows, and, sometimes, fantastic forms of our granite rocks, are merely the result of the disintegration of the softer parts by chemical and elementary action, which indeed is obvious to a very cursory examination. The actual operation may be traced in its various stages, shewing clearly that the only chisel ever employed was the tooth of time, the only artists, the agency of the elements. And that there may be natural fissures or cavities on the surface of the Wolf-rock, assaulted for so many ages by billows that would dash a first-rate ship to atoms in a few minutes, is far from being singular or surprising.

The arguments adduced by our old historians in proof of the tradition, refute themselves. In the first place, the sea is no shallower between the Land's-end and Scilly, than at equal distances from land, on other parts of the coast; and the *midway gulf*, or the Wolf-rock, happens not to be in that channel at all, but consider-

ably to the south of it; and as to the stories of fishing up pieces of doors and windows, and seeing tops of buildings, &c., had all the buildings, doors, and windows, of Cornwall, been placed there, the first tempest would have swept them all away, as pebbles before a torrent. The truth is, that no such relicks were ever discovered, or could have remained for discovery, in that boisterous channel of the Atlantic ocean.

But the geologist will rather examine the gigantic cliffs which bound the ocean at the Land's End, and the opposite Islands of Scilly, for indications of the mighty shock supposed by the tradition. The intermediate sea is about 300 feet deep—the land on either side, from 200 to 300 feet high. The sudden subsidence of a tract of country 30 miles in length, and perhaps 10 in breadth, to the depth of 500 or 600 feet, with the rush of the waters of the Atlantic into such a vast chasm, must have caused a great convulsion and disorder in the new formed cliffs on either side; of which however there is no appearance. The enormous masses of rock, on both sides exhibit, no signs of unusual derangement, but appear in the same natural order observable in other cliffs of like formation, on distant parts of the coast.

While we seek in vain for any evidence in confirmation of the Lionnesse tradition, there is much to corroborate that which relates to

an irruption of the sea over a tract of low woodland, now forming the northern part of the Mount's Bay, and comprehended within a line drawn from near to Cuddan point on the east side, to Mousehole on the west, a distance of about five miles.

Saint Michael's Mount, "*the Pilgrim's holy vaunt*," was named in Cornish, as Carew informs us, "*Caraclowse in Cowse*, in english, *the hoare* "*rock in the wood:* which now is at every flood "encompassed by the sea, and yet at some low "ebbs, roots of mighty trees are descried in the "sands about it." Later historians state, that this is probably the St. Michael's described in a charter of Edward the Confessor, as *near* the sea, "*Sanctum Michaelum qui est juxta mare.*" And that Florence of Worcester expressly asserts that it was formerly five or six miles from the sea, and enclosed with a very thick wood; and therefore called in British *Carreg lúg en Kug*, "*Le Hore Rok in the wodd.*" The Hore Rok, was certainly an appropriate name, as the weather beaten surface of its massy granite rocks, still give it a greyish hoary aspect, which would be more striking in contrast with "green-wood" scenery.

Tracing the north-west shore of the bay from the Mount westward to Newlyn, the ebb tide leaves a large space uncovered: the sea-sand is from one to two or three feet deep; and under

this stratum of sand is found a black vegetable mould, full of woodland detritus, such as the branches, leaves, and nuts of coppice wood, together with the carbonised roots and trunks of forest trees, of large growth. All these are manifestly indigenous; and from the freshness and preservation of some of the remains, the inundation of sand as well as water, must have been sudden and simultaneous; and the circumstance of ripe nuts and leaves remaining together, shews that the irruption happened in the autumn, or the beginning of winter. This vegetable substratum has been traced sea-ward as far as the ebb permits, and is found continuous, and of like nature.

Another, and more decided evidence of a tremendous shock, still in part exists; but, unless recorded, will itself be only a matter of tradition at no distant period. Except the projecting tongue of land, which forms the port and site of the town of Penzance, the bottom of the bay from Marazion to Newlyn, is bounded by a sand bank, locally termed the Green, having from time immemorial acquired enough of vegetation to warrant the name. This fragile bulwark daily and visibly wastes, through the operation of two powerful causes of consumption, viz. the quantities carried off for manure, and other uses, by the inhabitants of the adjacent country; and the continual encroachment of the sea on the

mouldering front, where every wave, as well as every stroke of the wind, makes some effacive impression.

The original length of this Green (or rather two Greens) was about three miles on the east, and one mile on the west of Penzance; and is already much shortened. The ancient breadth is unknown. The oldest notice, I have met with, is a letter still extant (belonging to the present representative of the Daniell family, Mrs. Ley of Penzance,) which was written in the reign of King Charles the Second, to the then proprietor of an estate which included part of the western green; and that part is there estimated at *thirty-six acres of pasturage.* Of which *part,* a small remnant of perhaps two or three acres, is all that remains of the *whole Green* on this side, which was, within the remembrance of persons, not long since deceased, a mile in length; and it is in the recollection of people still living, that the ground on which the youth of sixty or seventy years ago, exercised their contests of cricket and other sports, is now swallowed up by the sea. This agrees with the proportionably larger extent mentioned in the letter just alluded to; and if a like ratio of decrease may be assumed for a period of six or seven hundred years, its original dimensions must have been very large, in relation to the source from which, on any probable supposition, its formation could be derived.

Enough still remains to shew that the whole was a homogeneous mass of silicious sand:—the detritus of disintegrated granite:—that it had undergone ablution, which, dissipating some of the lighter parts, left the larger and heavier crystals of quartz predominant in the mass. It also appears, that its deposition on its present bed, was sudden and simultaneous, because the subsoil and vegetable remains continue in fresh preservation; and the whole bank forms but one stratum, containing no terrene and but few marine exuviæ. It is also remarkable that the natural sand, which forms the bed of the sea, is altogether unlike that of the *Green*, being much more comminuted, different in colour, and evidently the pulverised clay-slate, and elvan, of which the rocks of the inner section of the bay are composed. Here the question obviously arises, whence did this, originally prodigious, mound of granitic sand proceed? Knowing what vast accumulations of alluvial deposit have been made in many places by rivers and wintry torrents, one naturally asks, may not this have been formed in the same way? But the homogeneous structure of the bank, and the absence of terrene remains, decisively oppose that conclusion; besides which, the streams that empty themselves into this part of the bay, are mere rivulets, the longest course of which hardly exceeds five miles, and that too in general over a

killas, and not a granite soil. It is therefore quite evident that the Green was not an alluvial deposit from the land. We must therefore refer its formation to one of those tremendous convulsions of the elements, through which the boundaries of the sea have been so often, in some degree, changed.

But here again we are met by another difficulty. The sea sands of this and the adjacent coasts are either slaty, or calcareous, while this is, as beforementioned, purely granitic.

On examining the cliffs round the bay, we find that the great granite range intersects the shore on the east near to Cuddan-point, and on the west at Mousehole, precisely in the line which the supposed seaward boundary of St. Michael's Wood would have occupied. Now, if we may be allowed to imagine, that the mound of granite rocks was once continuous from Mousehole to Cuddan, and that these had been disintegrated, by chemical and elementary agency through a long course of ages, (of which there are examples at the Scilly Islands), we shall find a granitic supply adequate to the formation of the Green, and which, in every other direction, is sought for in vain. An extraordinary rise and convulsion of the sea, accompanied by a violent hurricane, might have carried such a mound over the adjoining low land, and have finally and irretrievably submerged it, as was

the case with the great estate of the Earl Godwin; and possibly at the same time when that irruption happened.

Dr. Borlase was inclined to suppose the submersion of St. Michael's wood contemporaneous with a great encroachment of the sea, mentioned in the Irish Annals to have occurred in the year 830. But Mr. Whitaker prefers the year 1099, citing Florence of Worcester, who says that "on the third day of the nones of Novem-" ber, 1099; the sea came out upon the shore, " and buried towns and men very many, and oxen and sheep innumerable." Also the Saxon Chronicle sub anno 1099, "This year, eke on " St. Martin's mass day, the 11th Novembre, " sprung up so much of the sea flood, and so " myckle harm did, as no man minded that it " ever afore did, and there was this ylk day a " new moon." If this was the period when the Godwin estate and other low lands were submerged, it will accord well with the tradition relative to the overflow of the Mount's Bay. But leaving this point to the decision of learned antiquaries, the geologist discovers in the actual bed of the sea, vegetable remains, so circumstanced as to prove beyond all possible doubt, that where they now lie, there they once grew and flourished. In the *Green* he finds equal evidence, that its whole mass, vast as it must originally have been, was wafted from a

distance (of at least several miles) by a sea, and not a land, flood, overwhelming the woodland, on which its formation was suddenly effected; and even now, in its almost final decay, presenting an awful memorial of some tremendous convulsion of the elements, written by the hand of nature in characters so plain, that he who runs may read.

The north coast of our peninsula was visited, in some remote period, by a different, but no less destructive calamity. A very considerable tract of cultivated land was overwhelmed by an immense inundation of sea sand, forming hills of an elevation several hundred feet above the level of the sea, varying in height and form, probably, with the undulating surface of the country thus submerged. But however varying in magnitude and appearance, the masses are alike in substance, being all calcareous sand, or rather comminuted marine shells. It might be a subject of curious speculation to enquire into the source of such a vast influx of matter, every atom of which was once the abode of animal life; but that inquiry would lead us far beyond the bounds of useful research.

It is remarkable, that not even a popular tradition remains of the time, or manner of this extensive devastation, which reached, with some distinct intervals, nearly forty miles in length. That it must have been witnessed by a nume-

rous population, is evident from the number of churches still remaining, more or less ingulphed; and on pieces of ground cleared from time to time, the lines of the ancient furrows are found strongly marked. It is also strange that no memorial of the event should have been discovered among the papers of the great proprietors, whose interests were affected by a calamity so destructive of valuable domains, and so alarming to the fears of the community at large. The particular circumstances of the catastrophe seem to have been already forgotten, when Leland visited the place, about three hundred years ago; and yet the period of its occurrence could not then have been *very remote*, because it is unquestionable that no churches would have been built, subsequent to the inundation, on the sites where we now find them; and those still extant are evidently not of an age much anterior to that of Leland himself.

Some allusion to this event was supposed to be discovered among ancient records of the Arundel family, fixing the period to the twelfth century; but the fact just noticed, of the situation and age of the parish Churches, decisively refutes that conjecture.

By the shifting of the sands, the ruins of ancient buildings have been discovered; but they do not seem to have attracted much noticc or investigation; and hitherto no relicts have been

found, that throw any light on the question, as to what period the submersion should be fixed. In this inquisitive age, we may expect more attention will be given to such an interesting enquiry after the remaining memorials of the *olden times*. It will be an encouragement to the researches of the persevering antiquary, to know, that owing to the dry and antiseptic nature of the sand, whatever may remain, is likely to be found in good preservation.

In some places, where the sand has been bored to a great depth, distinct strata, separated by a vegetable crust, are visible; which seem to indicate a succession of inundations, at distant periods: but it is possible, and not improbable, that this may be owing to a local shifting of the sands, because in other places the like series of strata is not found.

The phenomenon that will most powerfully arrest the attention and excite the investigation of the geologist, namely the formation of rocks, is here found in great perfection; at New-quay in particular, large masses of sand-stone have become sufficiently indurated to be used for architectural purposes. The chief cause of adhesion and induration appears to be an oxide of iron held in solution by the water, which percolates the sand, where the lapidification is now in process, and where it may be traced in its various stages. Whether any, or what other chemical

agencies may be also employed in concurrent operation, will be known, perhaps, to future mineralogists, who shall be able to penetrate deeper into the secrets of the great laboratory of nature. At present the scientific investigator may see her visibly at work; but should he hazard theoretic speculations, they may prove as little conclusive, as the notions which amused the philosophers of the last century have since appeared. Little more than fifty years have passed away since a learned author (of whom Cornwall is, and will be, justly proud), treating this very subject, affirmed that, "these imperfect stones, which are spread here and there among the Gwithian and Piran sands, are the accidental formations of a thinly dispersed *sparry or coraline juice,* blown up together with the spray of the sea. Let no one wonder that the spray of the sea shall produce such an effect; for that spar is suspended in all water is likely; but in particular waters is evident, from incrustations formed in the bottoms of culinary vessels, and in water pipes:—from petrified moss, and many other phenomena; and that spar is also found in sea water, must certainly follow, from the sea being open to, and ready to receive, all that springs will convey into it. All coraloid bodies and shells are formed of spar, modified and mixed so as to comply with the occasions of marine plants and animals." And again, "There is a kind

of stony, lapidific matter which runs through and mixes with the substance of all stones, and may justly be esteemed *the universal cement,* by which earths and minerals are combined into all the several orders and species of stones. This cement is either *spar, crystal,* or *diamond.*"

This ingenious hypothesis will cause a smile in mineralogists of the present age; but who can tell how much philosophers of the next, will smile at geological theories now in repute. For some, perhaps, they will grieve; and lament, that researches which are every where met by indications of infinite power and infinite wisdom, should, in any case, have excited doubts of the existence of the great Creator and Preserver of all things!

VII.—*On the Nomenclature of the Cornish Rocks.*

By JOHN HAWKINS, Esq. F.R.S., &c.

HONORARY MEMBER OF THE SOCIETY.

(Read October, 1818.)

I TRUST that I shall not incur a charge of presumption, if, in this stage of our existence as a scientifical body, I point out to my colleagues the necessity of a correct nomenclature. I allude to the very general application of foreign terms to our native rocks and minerals, in which mistakes are easily committed, that are injurious in their consequences to the progress of geology.

In pursuing this fascinating science in a country which has so many claims to our attention, it is natural that we should look, either for the correction or the confirmation of our observations, to our predecessors in this career, particularly the Germans. By a comparison of our own observations with those which have been published by these enlightened foreigners, we shall be enabled to ascertain how far any of the phe-

nomena, which have engaged our attention, are peculiar to this country; what circumstances of any interest may have been overlooked by us, or what links of the great chain of nature are here wanting: and thus, in a science where the experience of one observer can accomplish so little, and that little by such slow degrees, the united labours of Europe may be made subservient to our instruction.

This acquaintance however with the observations and the discoveries of our predecessors cannot be obtained without some difficulty, whether it be in the study of a foreign idiom, or in the correct application of the synonyms of those mineral bodies, which are the objects of our examination; for it is mortifying to be obliged to confess, that except in the school of Freyberg, no serious or very successful attempts have been made to settle the language of geology.

It is therefore fortunate for this science, that so many of the writers who have acquired any celebrity in it, have been educated in this school, and consequently have been led to adopt the same terminology. Nor is it less fortunate for the advancement of this science, that Saxony, which has been the principal theatre of their observations, is of all countries, that which presents the greatest variety of interesting geological phenomena.

And here I cannot forbear to express the sense which I feel, of the obligations which I owe, in common with so many others, to the father of this school, the celebrated Werner. This man seems to have been born at that particular period in the history of a science, when a genius like his was most wanted to give strength and consistency to its advances. It was he who first methodized and depurated the labours of his predecessors, created a new mineralogical language, taught a more natural method of observing, and pointed out a proper division of labour in these pursuits.

Placed at an active period of life in the mining and mineralogical chair of Freyberg, and in the very center of the Saxon mines, those abundant sources of geological instruction; he had all the means of effecting whatever his zeal or his genius suggested. The eloquence of his delivery, his scientific precision, his enlarged conception of things, his attention to the wants of his hearers, soon drew around him pupils from all the countries of Europe, and made Freyberg the center of information in all that relates either to the art of mining, or to the science of mineralogy. It was frequented by the natives of every part of Germany, (with the exception of the Austrian states, which had a school of their own,) most of whom were deputed by their respective governments to perfect

their mining education there. At the academy of Freyberg were assembled Russians from the farthest part of Siberia, Swedes and Norwegians, Poles, Frenchmen, Italians, Spaniards; and in the year 1793 I found there two Brazilians. When the Spanish government in 1786 judged it adviseable to introduce the improved process of amalgamation into the countries of South America, most of the young mining proficients, who were selected for that purpose, were the pupils of Werner, and my fellow students.

From these causes has arisen that general diffusion of the mineralogical language and method of Saxony, which, by giving such an uniform direction to geological enquiries, has so much conduced to the advancement of this science in the last thirty years; and hence it is, that the name of Werner is become so well known in every region of the globe, from the mines of Siberia to those of Peru and Mexico.

If I should be asked in what particular department of science I feel most partial to the merits of my instructor, I would point out that of geology. It is here that I think them preeminent. His accurate mode of investigation, the facilities which he enjoyed for personal observation, and the numerous opportunities which presented themselves for collecting information through others, enabled him to classify

and to arrange all the known strata of the earth, and to unfold, as it were, the order of nature in their formation.

The language of his country was, I think, particularly favourable to these views. It is rich in words both simple and compound, and what the English (if they adopt not the Latin idiom) find so necessary to express by a circumlocution, the Germans very readily and significantly render by a compound word of their own.

Can we justly blame Werner, if, in respect to the nomenclature of natural bodies, he adopted the terms that were in common use? His choice, as is often the case in matters of this nature, was determined by a balance of inconveniences. Moreover, the very general diffusion of mining ideas throughout that part of the continent, had already created a language which, although rude, and even barbarous, and to a certain degree variable in its application, comprehended nevertheless most of the new objects of geological interest. Its adoption therefore was calculated to accelerate the advancement of this new science in Germany, from whence, in the natural course of things, it found its way to other countries, which have since admitted it to all the rights of naturalization.

It is the correct application of these terms of foreign origin, whenever it may be necessary to make use of them, that I now venture to recom-

mend to our society. It is a key which will certainly open to us a great treasure of information, and give an additional value to whatever we may chuse to communicate.

I am induced to be the more explicit on this subject, by the use which has lately been made of the term grey-wacke.

This term, so well known in the dialect of the Saxon miners, has been applied to a rock-formation, which occurs in some parts of Germany, where it constitutes the greater portion of that group of mountains, known by the name of the Hartz Forest.

Werner, who had the means of making himself perfectly acquainted with the natural history of this rock, has classed it among those which he supposes to have been deposited during the passage or transition of the earth from its chaotic to its habitable state. It is considered as the most important of these transition rocks, for with it, to use the language of Jameson, commences a new geognostic period, namely, that of mechanical depositions. The characters of the mass do in fact justify, to a certain degree, such an inference; for its coarser grained varieties are visibly composed of an aggregation of particles of quartz and hornslate; which particles have the appearance of having been somewhat rounded by attrition, and are cemented together by the matter of argillaceous slate.

It would have been more consistent with the notion of its derivative origin, had every definition of this rock-formation been confined within these limits: instead of which we find it extended by later geologists, through all the regular gradations observable in the grain of the mass, to argillaceous slate, which has never been suspected of being derivative; and after an unavailing attempt to maintain the line of distinction between these two rock-formations, by some external characters, which are not sufficiently constant to be of any importance, it is now pretty generally acknowledged that the terms grey-wacke slate and argillaceous slate are convertible, it being impossible without the aid of petrifactions, to ascertain where the one ends and the other begins.

A dilemma so unfortunate as this is, ought to have suggested the probability of some error in the process of reasoning upon which these distinctions are founded, and might have sooner led to its correction; for as the priority of formation was confessedly due to that slate which contained no petrifactions, it was natural to conclude that the order of transition, if there were any, would be conformable with the march of nature. It is surprising, as the derivative origin of the grey-wacke rests so much upon this view of the subject, that there should ever have been any other opinion in respect to this order,

and that the grey-wacke rock, instead of terminating the formation of argillaceous slate, should have been regarded as its archetype, or the point from which it proceeded. So general nevertheless has been this misconception, that the terms grey-wacke and grey-wacke slate have been applied, without reserve, to strata which exhibit in a very imperfect manner, if at all, the derivative character, and which are altogether destitute either of petrifactions or of the limestone beds containing them;—in short, to a primitive rock, in no respect whatever differing from our argillaceous slate: the consequence of which is, that this latter and more ancient denomination is now, in the literal sense of the word, losing ground, and gradually becoming obsolete.

It does not appear that Werner had ever contemplated this abuse of a denomination, which the progress of discovery, at the period when he first adopted it, seemed in his opinion to justify. Struck with the derivative nature of this rock, and the organic remains, which were occasionally observed in the mass, he found it expedient to separate it in his earliest systematical arrangement, even from the argillaceous slate into which he had traced its transition, and with which it alternated. Accordingly, in the short or elementary classification of mountain rocks *(gebirgs-arten)* which he

published in the year 1787, the grey-wacke is placed among the derivative rocks at the head of the secondary class, but no mention is made of grey-wacke slate; so little was he then disposed to include in this new denomination, any thing which possessed not the true derivative character. The same arrangement subsisted at the period of my second visit to Freyberg in 1793; but on my return thither in the year 1798, I found that some very important changes had taken place in the order of the Wernerian arrangements; the class of transition rocks having been introduced between the primitive and the secondary; at the head of which new class, was placed that argillaceous slate, which had been observed to contain organic remains; the true grey-wacke being here stationed at the end of the series. The primitive sort of argillaceous slate, on the other hand, still kept its place in the system of arrangement, next to micaceous slate. Admitting, as Werner did, that nature had repeated the same operations at various intervals, there was nothing in this separation of the argillaceous slate into two distinct classes, which could be deemed unscientific.

And here I could have wished, that the nomenclature, as well as the arrangement of these rocks, had remained stationary, or at least subjected to such limitations as would have obviated all that confusion which has since arisen. The chief cause of this evil, I suspect to lie in

our ignorance of the true nature of grey-wacke. It has been generally considered as a derivative rock, and this opinion is necessarily connected with the notion of a previous disintegration of strata of argillaceous slate, and the removal or reunion of their fragments. But, if this had been the case, nature unquestionably would have left a bold line of distinction between strata, the origin of which had been so essentially different: whereas no such line exists, the transition of one rock into the other being insensible. This shews that both owe their origin to the same mode of deposition, the nature of which has been apparently both chemical and mechanical, without being *derivative;* except in those cases, where the fragments of one bed are found inclosed in another. By our adoption of this hypothesis, we should indeed exclude grey-wacke, as a distinct rock-formation, and admit it only as a subordinate one, which may have some inconveniences, although none that I know of, that can be compared with those arising from its present station in the system; where it seems to be perpetually struggling not so much for existence, as for exclusive dominion.

As it appears, therefore, that the two rocks here mentioned, cannot be separated in any system of geology, without some violence to nature; would it not be adviseable to include both under the general denomination of the older;

distinguishing the primitive sort of argillaceous slate, from that which is of more recent origin; and considering the true grey-wacke as appertaining to the latter?

Being desirous of ascertaining the synonyms of the rocks which constitute the principal strata of Cornwall, I transmitted to Mr. Werner in the year 1793 a well chosen collection of specimens of some of their varieties; and in the autumn of the same year, I had the satisfaction of hearing his decision upon them. No doubt was expressed of the nature of our metalliferous rock, the *killas*. It was pronounced to be a genuine *thon-schiefer*, or argillaceous slate, in no respect differing from that which occurs in Saxony.

As the belts of iron-stone which encircle the granitical hills in Cornwall had very early engaged my attention, I felt particularly anxious to submit some specimens of this interesting rock-formation to the examination of such an experienced observer. Those taken from the neighbourhood of Penzance were, after a rigid scrutiny, pronounced to be hornblende-rock intimately mixed with the constituent mass of argillaceous slate, and in part genuine hornblende-slate. Some specimens of iron-stone from Penpillic and Corrogat in Trewardreth parish, which I procured from the late Mr. Rashleigh of Menabilly, were characterized by Werner as follows:—" This rock is an intimate " mixture of hornblende and dense or compact

"felspar, in which a little quartz may be occa-
"sionally perceived. Some specimens bear a
"very near affinity to the horn-schiefer of the
"Swedes."

To the judgment of the same accurate observer I submitted various specimens of our Cornish elvan, and the result of their examination was expressed in the following words. "The globules in the Chyanoweth elvan consist
"of quartz and mica intimately mixed. This,
"together with the elvan from Pedenavonder
"in Sithney, perfectly resembles the substance
"of the granitical veins near Eibenstock and
"Johangeorgenstadt, and is in fact a fine grain-
"ed variety of granite. The elvan from Port-
"kellis-Bal, and Huel Whidden in Breage, is
"the same, with this difference only, that the
"felspar is dissolved into porcelain earth. The
"elvan from Polgooth is an argillaceous por-
"phyry, which in the lowest levels of the course
"or channel, approximates to the same fine
"grained granite which composes the veins at
"Eibenstock. The Pentuan stone is common
"porphyry."

I shall now lay before the society some thoughts and reflections that have naturally arisen during the consideration of this subject.

There are evidently numerous varieties of the Cornish elvan, in some of which may be traced the transition from porphyry into granite. The mass contains, moreover, in a state of dis-

persion, many extraneous crystallized substances, and is intersected by veins of different minerals, which veins are of contemporaneous formation. The circumstances under which the elvan occurs, as we learn from the instructive report of Mr. Carne, are in many respects singular, and inasmuch as they are connected with the natural history of our tin and copper lodes, highly important. We have still, however, but an imperfect knowledge of these, and I trust that those members of our society, who may have opportunities for collecting further information, will not neglect to avail themselves of them. By way of hint to assist their enquiries, I beg leave to mention that in addition to the many extraneous substances which have been observed in the elvan, may be placed the tourmaline which I found in a quarry of this rock between Grampound and St. Austle. I shall moreover take this opportunity of recording a very old observation of my own, which throws some light, imperfect as it is, on the mode of its formation. I allude to a smooth spherical mass of elvan, about the size of a large cannon-ball, which I once found embedded in a solid block of the same rock. This ball of elvan appeared to have acquired its shape by long attrition, before it became inclosed in a fresh deposition of the same mass.

I shall conclude with recommending a more accurate discrimination of all the varieties of

our granite, and an enquiry into their relative situation. In an attempt which I once made to express by colours on Martyn's map, the different strata of the county, I perceived that the granite hills formed several distinct and insulated groups of a circular form. Each of these in my opinion deserves a particular examination, with a view to the decision of a question of no small importance, whether these insulated portions of granite are, strictly speaking, of homogeneous formation. That variety of granite, which, besides the three constituent parts of the mass, in their usual relative proportion, contains large perfect crystals of felspar in a state of dispersion, appears to me to be peculiar to the west of England, although even there not of general occurrence. The Dartmoor granite is of this kind; likewise that of St. Just, Sancreed, Sennen, St. Levan, Buryan, Paul, Madron, and Gulval. Should the remaining parishes of the peninsula westward of Penzance, be composed of it, we must necessarily draw this inference, that the strata which constitute the granitical formation in Devon and Cornwall, belong to two or three different periods; that is to say, they indicate as many pauses in their deposition, which allowed perhaps of some modification of temperature, and either a quicker or a slower passage from a solvent state to that of a crystallized deposition.

VIII.—*On the Temperature of Mines.*

By JOHN FORBES, M.D.

HONORARY MEMBER, AND LATE SECRETARY, OF THE SOCIETY.

(Read September, 1819, & October, 1820.*)

THE subject of the temperature of mines naturally divides itself into two parts, according as it relates to the simple history of the phenomena, or to the investigation of the causes and relations of these. In this paper I shall adhere to this distinction, as best calculated to give a clear and precise view of the very interesting and important matters to be considered.

In the first, or historical part, I shall strictly confine myself to the narration of facts; and, with a view to greater accuracy, shall transcribe the journals I wrote at the time of observation, in the galleries of the mines. In these journals

* In transcribing these two papers for publication, I have thrown them into one, and thus, in some respects, new-modelled them. I have also added some few facts; but regret that want of time has prevented me from making many other very obvious and desirable alterations. *Chichester*, May, 1822. J. F.

it will be seen that I have been particular in noticing many of the concomitant circumstances; but I now very much regret that the details are not more comprehensive, and that many opportunities of making further observations, still more satisfactory, were neglected, partly from inattention and weariness, but principally, from ignorance of their importance. I trust, however, that many of my observations are recorded with sufficient minuteness to enable others to form a correct judgment of the legitimacy of the conclusions which I may attempt to deduce from them, or themselves to form others which may seem more just. I can, at least, vouch for their general accuracy.

In the second division of my subject, when I shall have to leave the safe ground of history for that of philosophical inquiry, I fear that I shall stand much in need of the indulgence of the society. In a path so new to me I shall feel my footing very insecure: but as I shall attempt little beyond the task of a pioneer and guide to those that may come after me, my feebleness will, I trust, be both less perceptible and more readily overlooked.

PART FIRST.

BEFORE proceeding to read my registers, it may be proper, with a view to their better comprehension, to premise a few brief remarks

on the nature and interior economy of the mines in which the observations were made. This will save explanations during the detail, and enable those who have never visited the interior of mines, to enter upon the subject of their temperature with greater facility.

1. Perhaps the clearest idea we can convey to others of the nature of a metalliferous vein, or lode, is afforded by the old thoretical notion, of a narrow rent in the rocky crust of the earth, approaching more or less to a vertical direction, and filled with metallic ores. The object of mining is to break down, and transport to the surface, the contents of this supposed rent,—in other words, to cut out from the containing rock, this thin metallic plane. To effect this, galleries, called in Cornwall *levels*, are driven horizontally on the vein, one above the other, and the ore, &c., produced by their excavation, are transported to the surface by vertical galleries, called *shafts*, cutting the former at right angles. The horizontal galleries are, in the first instance, about two feet wide and six feet high, but varying, of course, according to circumstances, and being frequently extended much beyond their original dimensions. They are driven one above the other at intervals of from 10, to 20, or 30 fathoms. When extended to a certain distance from the original shaft, it is necessary, for the sake of ventilation, as well as

for other reasons, to form a second, which traverses all the galleries in the same manner as the first. The distance between shafts is very various,—being from 20 to 100 fathoms. Frequently a communication is made between two galleries by a partial shaft (called a *wins*), in the interval between two shafts. When there are more than one lode worked in the same mine, as frequently happens, galleries often run parallel to each other at the same depth. In this case they often communicate by intermediate galleries, driven through the rock (or *country*, as it is called in Cornwall,) which are termed *cross-cuts*. A mine thus consists of a series of horizontal galleries, generally one above the other, but sometimes running parallel, traversed at irregular intervals by vertical shafts, and all communicating together, either directly or indirectly.

2. A person unacquainted with the details of mining, on being informed of many hundreds of men being employed in a single mine, might naturally imagine that a visit to their recesses would afford a picturesque and imposing spectacle of gregarious labour and bustle, tremendous noise, and much artificial brilliancy to cheer the gloom. Nothing however is further from the truth, as far as regards the mines of Cornwall; for like their fellow labourers the moles, the miners are solitary in their operations.

Seldom do we find more than three or four men in one gallery at a time, where they are seen pursuing the common operations of digging or boring the rock, in the inner extremity of the gallery, by the feeble glimmering of a small candle, with very little noise, or much latitude for bodily movement. Very seldom are they within the sound of each other's operations, except occasionally when they hear the dull report of the explosions. In the vicinity of the main shaft of the mine, indeed, the incessant action of the huge chain of pumps, produces a constant but not very loud noise, while the occasional rattling of the metallic buckets (for conveying the ore) against the walls of the shaft, as they ascend and descend, relieves the monotony both of the silence and the sound. Still every thing is dreary, dull, and cheerless; and you can be with difficulty persuaded, even when in the richest and most populous mines, that you are in the center of such extensive and important operations. What adds greatly to the impression of tameness is the extreme darkness and dirtiness of the galleries. There is no light whatever but that afforded by the candles of the workmen, and by those carried by yourself and guide: while the universal presence of water soaking through the crevices of the galleries, and intermixing with the dust and rubbish, keeps up a constant succession of dirty

puddles through which you must pass, besides being frequently obliged to crawl on all-fours through passages too low to admit you in any other manner. The galleries are extended by breaking down the looser parts by the pickaxe, and by rending the more solid by gunpowder. Each miner has a candle, which is stuck close by him, against the wall of his gallery, by means of a piece of clay; and besides those employed in extending the gallery, there are generally one or two boys employed in wheeling the broken ore, &c. to the shaft. Each of these boys has also a candle affixed to his wheelbarrow, by the universal subterranean candlestick, a piece of clay. A certain band of men (called, however numerous, *a pair*), generally undertake the work of a particular gallery. These subdivide themselves into smaller bodies, which, by relieving each other at the end of every six or eight hours, keep up the work uninterruptedly, except on Sunday. By means of this subdivision of the *pairs*, there is in general not more than one third of the underground labourers below at any one time. Notwithstanding this incessant labour, the progress of the miner in excavating his gallery is, in general, very small: one, two, or three feet in a week, or a few inches daily, is often the whole amount of the united operations of 20 or 30 men. In loose lodes, and in killas districts, they often cut more than this, but

often they do not cut so much. It is to be recollected that the lode is very rarely so wide as the gallery, so that it becomes necessary, in order to continue this of the proper size, to hew through the solid rock on each side, which is often very hard, even when the lode is soft. The Cornish miner never sleeps nor eats under ground, but returns to *grass* (the technical name of *the surface)* and to his home, often many miles distant, at whatever depth he may be working, when relieved. The mode of ascent and descent in mines is by means of vertical ladders fixed in the shafts.

3. Any person who calls to mind the manner, object, and results, of the common process of sinking wells, will be prepared to expect the presence of water in mines. The quantity of this varies very much in different mines at the same time, and in the same mines at different times. Some of the circumstances that occasion this difference are very obvious, for instance, the topographical relations of the surface, the nature of the rock and lode, the number and size of the lodes, cross-courses, &c. Many galleries, both on the lode, and through the *country*, are quite dry, but in general, the reverse is true. Commonly the water oozes almost imperceptibly from the lode and walls of the galleries, and gradually accumulates, as formerly mentioned, so as to form puddles and pools of

considerable size under the feet of the miners; and it is very common to find the bottom of long galleries covered, for some hundred feet, with dirty water of this kind to the depth of several inches, and sometimes of a foot or more. Sometimes, but very rarely, we meet with brisk streamlets or springs gushing from the lode. In most mines we meet with currents of water flowing towards the pumps, from the upper galleries, or from parts of the mine that have been abandoned.

The quantity of water in mines is most abundant during the winter, or rather in the spring, some time after the termination of the rainy season. This fact is easily accounted for, especially in deep mines, by the length of time that the superficial water requires to percolate to a considerable depth. Inattention to this circumstance has given rise to an erroneous idea, still prevalent among miners, that *a dry easterly wind raises the springs.* The fact seems to be, as has been satisfactorily shown by Pryce, that the "dry easterly winds" of the spring generally set in, in this country, about the period at which the main body of the rain, fallen in the preceding months, has been able to attain, in its slow progress through the lodes and strata, the bottom of the mines.* The variation in the

* See Pryce's *Mineralogia Cornubiensis*; also "Observations on the Climate of Penzance, &c." by John Forbes, M.D. Penzance, 1821.

quantity of water is much more considerable in shallow mines; these soon experiencing the variations of humidity at the surface, according to the seasons. It is a curious fact that several mines worked under the sea, have been found less subject to the percolation of water from above, than many others. This was formerly observable in Huel Cock, in the parish of St. Just, and is at the present time in two mines in the same parish, Botallack, and Little Bounds.

For keeping the workings from being inundated, each mine is furnished with a chain of pumps, extending from the bottom to the adit-level, worked by a single pump-rod; each pump receiving the water brought up by the one immediately below it. All the water of the mine, below the adit-level, eventually finds its way into the bottom of the mine, or *sump*, whence it is finally elevated to the adit, through which it flows, by a gentle descent, to the surface. The quantity of water discharged by the pumps from many of the Cornish mines is very considerable: thus Huel Abraham discharges, from the depth of 1440 feet, about 2,092,320 gallons every 24 hours; Dolcoath, from nearly the same depth, 535,173 gallons in the same time; and Huel Vor, from the depth of 950 feet, 1,692,660 gallons.

4. In giving an account of the ventilation of mines it is necessary to anticipate, in some

degree, the result of our investigations respecting temperature, and to notice the degree of heat that is found in the air, water, and earth, at the bottom of mines. The precise degree of this temperature will be hereafter stated; it will suffice here to mention that it exceeds 80°. in the deepest mines; that it amounts to 70°. at a less depth than 1000 feet, and that it is 5°. or 6°. above the mean temperature of the climate at no greater depth than from 200 to 400 feet. The existence of this temperature at the bottom of mines (however produced) will, of itself, necessarily occasion a constant circulation of air upwards, through the shafts; and as what ascends must be replaced by the air above, there will, of course, be a constant current downwards through the same or other shafts. The extent of ventilation in mines will depend on many circumstances, more especially on their depth, the number of shafts, the degree of communication between the different galleries, and also on the state of the wind at the surface. The cooling effect of high winds is very perceptible even at the bottom of shallow mines, and it appears that the currents of air in the very deepest mines are considerably influenced by the force and direction of these.

For the following observations on this subject, relative to the magnificent mine of Dolcoath, I am indebted to Mr. John Rule, Jun.

one of the superintendants. "I have made some experiments to ascertain the direction of the currents of air in this mine, and find that in 25 of our principal shafts, (the whole of those open on the main lode) 13 have a strong current of air downwards, and 12 about the same degree of current upwards: they differ however with respect to the strength of the currents, some being very strong, others less so. I never made any experiments to ascertain the currents of air before, but from common observation, I am enabled to state that they vary as the wind does, so that those shafts which sometimes have a current downwards, on a change of the wind have an upward current, and *vice versa.* The same thing takes place with regard to the *levels* underground; changes of wind making the current of air run in opposite directions at different times. The strength also, of the currents underground, depends upon the wind at the surface; when it blows hard the current is strong underground and *vice versa.*

"We find no want of air underground, even in the deepest parts, where a communication is made from one level to another by means of a shaft or a *winds,* or from one shaft to another by a level. The current of air is frequently so strong even towards the bottom of the mine as sometimes to blow out a candle: in fact we never find a deficiency of air unless it be in

a level extended a considerable way from a shaft, without having a communication with any other part; or in a shaft sunk far below a level; in which cases we are frequently under the necessity of having recourse to some artificial means to procure air in the part wanting it.

"I ascertained the currents of the shafts at the surface by throwing feathers, pieces of paper, and straw into them. In many cases the currents were so strong as to carry these things rapidly upwards to the height of several yards."

Though these currents in the shafts and more open galleries are considerable, it is still true, that in the great majority of the galleries no current, or one that is very slight, is perceptible; and that in all such galleries as communicate only by one extremity with a shaft, or with other levels by a *wins* at some distance from their inner extremity (both of which kinds constitute the greater number of the working galleries), there is no current whatever, and in fact, no possibility of their being one. Many of these galleries are several hundred feet in length, with no other outlet but their extremity at the shaft. A sufficient proof of the general stillness of the air in mines is afforded by the fact of lanterns being unknown in them; and during all my visits to these gloomy regions I never saw the candle extinguished by a current of air, more than once or twice.

Owing to the absence of the generating materials in the mines of Cornwall, the hydrogenous gases of coal mines are entirely unknown. Accidents, however, occasionally though very rarely occur, from the accumulation of other of the irrespirable gazes in long abandoned galleries *; and it is very common in sinking deep shafts, or driving long galleries, to find the air so vitiated by respiration and combustion, and by the gazes from exploded gunpowder, as to oblige the miner to fix his candle in almost a horizontal direction to keep it from being extinguished. In cases of this kind artificial currents are occasionally produced by means of air-pipes, &c.

Having premised these explanatory details, I now proceed to lay before the society the register of my observations on the temperature of mines. To the account of each mine I shall prefix a few particulars which it may be important to keep in mind, while considering the details.

* Accidents of this kind appear to have been more frequent formerly, probably from less attention being paid to the ventilation. "While they thus play the mouldwarp," says Carew, "unsavoury damps do here and there distemper their heads, though not with so much danger in the consequence, as annoyance for the present." Page 37, Dr. Borlase says death from this cause never occurs; but both Pryce and Polwhele relate several instances of the kind. I have myself never heard of any occurrence of this kind (1820). Since leaving Cornwall, I have noticed in the public papers a statement of a fatal event from this cause, 1822.

1. HUEL NEPTUNE. Copper mine, situated in killas.

Height above the level of the sea, about 200 feet.

Depth, at the period the observations were made, 550 feet.

(Depth in 1822, 750 feet.)

Number of men employed under ground 120.

Expenditure of candles per month 1200 lbs.

Expenditure of gunpowder ditto 250 lbs.

Quantity of water discharged per day 216,000 gallons.

Temperature of this at the adit at the time the observations were made 60°. (in 1822, 62°.)

Has been working 11 years (1822).

Huel Neptune, like most of the Cornish mines, consists of an old abandoned and shallower part conjoined with that now in operation. It was in the former (western) part that I began my observations; and all those at or above the depth of 342 feet were made here. I shall prefix a letter to each of my observations in my account of this and the following mines, for the sake of correct and easy reference. In all cases I shall reckon by *feet;* and in estimating the *depth* of mines shall reckon from the *surface,* and not from the adit-level, as is customary. I use Farenheit's thermometer; and, for the sake of brevity, shall frequently content myself with put-

ting down the number of degrees without repetition of the words *thermometer, temperature, &c.*

April 21, 1819.

a. Air at the surface in the shade 54°.

b. Air in the mouth of the engine shaft by which I descended (engine at work) 58°.

c. 114 *Feet* within the shaft, air 58°.

d. 150 *Feet.* The adit-level. In the entrance of this, air 57°; water as flowing from the pump 60°.

e. *Same level*—240 feet from the shaft. Water and air precisely the same as in last observation.

f. 200 *Feet.* Old gallery.—A large excavation on the lode. Air quite still—no water. Air 56°; loose dry earth in the bottom of the gallery 55°.

g. 246 *Feet.* Level on the lode. Gentle breeze coming from an old shaft sixty fathoms distant. Air 56°; loose dry earth 57°.

h. 294 *Feet.* A large excavation on the lode in a long abandoned level. Air, quite still, 56°; loose dry earth 55°.

i. *Same level.* Midway between two shafts which are at a considerable distance. Air and earth as in *g*.

k. *Same level.* Pool of standing water in the bottom of the gallery, several fathoms long and a foot deep. This water 55°. (Pump water in this level 60°.)

l. 342 *Feet.* In a cross-cut forming a considerable angle with the level on the lode; water of a large standing pool 54°.

m. *Same level.* On the lode. Bottom of the old engine shaft, imperfectly covered at top, through which a glimmering of light can be discerned above. Air 58°; loose dry earth 56°.

n. 402 *Feet.* Large streamlet of water running *towards* the engine shaft: water of this 57°.

o. 450 *Feet.* An open level communicating with the engine shaft. No men working near, but they often pass through this gallery. Air 60°. (Pump water here 60°.)

p. 540 *Feet.* Lowest level in the mine. A large excavated space adjoining the engine shaft, where the pump and *whim* * are at present in action. A small gallery on the lode opens into this space, in the inner extremity of which (about 30 or 40 fathoms distant) men are now at work on the lode. No perceptible current of air. The mine now feels much warmer and closer; and fumes of gunpowder are very perceptible. Air 64°; loose earth 63°.

q. *Same level.* Inner extremity of the gallery mentioned in last observation, about 30 fathoms from the shaft, very close and hot; eight men constantly at work on the lode. Air 70°. Small standing pool in the same place, 4 inches deep. Water of this 67°. Thermometer buried

* The apparatus for raising the ore-buckets from the bottom of the mine.

in loose slatey rubbish just broken from the sides of the lode 70°.

r. Same gallery, at its outer extremity where it joins the shaft—Air 68°.

Postscript. May 1822. I learn from my friend Joseph Carne, Esq. that Huel Neptune is now 756 feet deep, that is 216 feet deeper than at the time I visited the mine, and that the temperature of the pump water as discharged at the adit is 2°. higher, viz; 62°.

2. Botallack. Tin and copper mine.

Height above the level of the sea about 40 feet.

Depth at the time the observations were made, 570 feet.

(Depth in May 1822, 672 feet).

Number of men employed underground 150.

Expenditure of candles per month 1200 lbs.

Expenditure of gunpowder ditto 600 lbs.

Quantity of water discharged by the pump daily 57600 gallons.

Temperature of this at the adit in 1819, 62°. in 1822, 67°. Has been worked 17 years, (1822).

July 26, 1819.

a. Air at the surface, in the shade, 64°.

b. Small stream of water conveyed in an open conduit from a considerable distance, employed for the washing of the ore &c, 63°.

c. 42 *Feet* below the mouth of the engine shaft, the adit level open to the cliff. Air (quite still) 62°. Water discharged by the pump 62°.

d. 96 *Feet.* Level on the lode. Air (quite still) 58°; a deep pool of water 56°.

e. 126 *Feet.* Near the engine shaft: still air 59°; small pool of water 57°.

f. 198 *Feet.* Level on the lode—near the engine shaft—midway between two other shafts, eighty fathoms distant. Air (quite still) 60°: pool of water in the bottom of the gallery 58°.

g. *Same level,* 50 fathoms from the place of last observation, results precisely the same.

h. 240 *Feet.* Level on the lode—very dry, air perfectly still. Thirty fathoms distant from any shaft—air 61°; loose earth 60°.

i. 300 *Feet.* On the lode, at a distance from any shaft, air (quite still) 61°; deep standing pool in the bottom of the gallery 59°.

k. 390 *Feet.* Level under the sea, on the lode. Beneath this gallery there is an "old working" which has been long abandoned, and which is now filled with water to the level of the bottom of this gallery. This excavation is ten fathoms deep, and of considerable length. The water contained in this, which is quite salt, is 62°. Air in the gallery 66°.

l. 450 *Feet.* Level on the lode. Several men at work. Air near the men, and also at a distance, 66°.

m. 510 *Feet.* Level on the lode. Near the engine shaft, a gentle current of air 64°.

n. *Same level.* In the inner extremity of the gallery where the men are at work, air 72°; same place, small puddle of water (not a pint) under the feet of the miners 69°; loose fragments of slate broken at that instant from the walls of the lode 68°.

o. 540 *Feet.* Lowest level of the mine, having no communication with any other part but the gallery immediately above it, and this only by a *wins.* In this excavation the air is quite still, and there is very little water. Air 66°; water 67°.

N. B. The whole of this mine is worked under the sea-level, and a considerable part of it directly beneath the bed of the sea. All the water in it is saline, but much less salt than the sea water at the surface. A singular fact was mentioned to me in this mine by one of the miners. In one of the galleries at a considerable depth, there existed for a long time a single stream of fresh water, which, like the fabled *Fons Aradius* of the mariner, was pure and sweet amidst the surrounding brine. It came from the roof of one of the galleries, and was so small as to be rather a succession of single drops, than a continuous thread of water. While it lasted, the miners were in the habit of keeping a bottle suspended under it to collect the water for

i. 288 *Feet.* The mine is now in granite. Level on the lode, very dry. Eight fathoms from the shaft and about eighty from the inner extremity of the gallery, in which two men and two boys have been working the last four months, There is a considerable current of air: this 54°.

k. *Same level,* 30 fathoms from its inner extremity: Air 56°. Thermometer buried four inches in the loose earth 54°.

l. *Same level,* at the inner extremity, where the men are now at work on the lode, which consists of quartz, with brown hæmatite, and a capel of loose crumbling granite. Thermometer buried in the soft and previously untouched growany earth for ten minutes, 59°; in a pool a few inches deep 59°; in the air 62°.

m. 312 *Feet.* Lowest level now worked. No men here at present. Twelve fathoms from a shaft—a perceptible current of air, and also a small streamlet of water. Thermometer in a pool of stagnant water, one foot deep, out of the direction of the currents of air and water, 54°.

n. *Same level,* but on another parallel lode which has not been worked for six years. The inner extremity of this gallery is 30 fathoms distant from any outlet or communication whatever, and 48 distant from the nearest shaft. In the very extremity is a pool of perfectly fresh water (though we are now directly under the

bed of the sea), six inches deep and several feet wide: this water 56°; air in same place 57°.

o. Same depth. A cross-cut uniting the two galleries already mentioned—a perceptible current of air, and a shallow stream of water running towards the pump: this water 54°.

p. Same depth, but on a different lode. No person at work near this. Beneath this gallery there is an "old working" communicating with it by a *wins.* This excavation is six fathoms deep and ten long. It is now quite full of water, and has been so for at least two years. Doubtful if any water is now running into this reservoir. This water 55°; air in the gallery, which is quite still, 54°.

4. Ding Dong. Tin mine. In granite.
Height above the sea level about 400 feet.
Depth from the surface 606 feet.
Number of men employed under ground 120.
Expenditure of candles per month 900 lbs.
Expenditure of gunpowder ditto 300 lbs.
Quantity of water discharged by the pumps daily 50,000 gallons.
Temperature of this at the adit, 61°.
Has been worked eight years.

July 26, 1820.

Ding Dong, like Huel Neptune, consists of an old and shallower mine not now worked, conjoined with the part now worked, which is

deeper. These two portions are united by means of a gallery at the depth of 50 or 60 fathoms under the surface. To the westward of this more antient part of the present Ding Dong there is still an older mine (Huel Malkin) adjoining, but not, I believe, actually communicating with the present mine. Huel Malkin has been entirely abandoned for many years. It was through the older portion of Ding Dong that I descended, and proceeded to the part of the mine now worked by the gallery that unites them.

a. Air at the surface in the shade 65°.

b. Air in the shaft, from the surface to the adit, which is 72 feet *from grass*, 58°. This shaft is driven perpendicularly through the solid granite, and not on the lode.

c. 132 *Feet.* In the shaft; no apparent current of air; water dripping all round: air 55°. N. B. As this shaft communicates only with the surface and the fifty-two fathoms level, it must come from one of these sources.

d. 384 *Feet.* At the bottom of the shaft, where it joins the level, on the lode; no perceptible current of air, but a constant dropping of water; no men at work within forty fathoms: Air 55°.

e. 444 *Feet.* At the bottom of the shaft. Air 55°; small pool of water 54°.

f. Fifty fathoms to the westward of the shaft this gallery terminates. At its inner extremity four men have been employed for the last five weeks in cutting the barrier which separates this part of the mine from the older mine to the westward. They are now at work, and have just succeeded in piercing the barrier, by a small opening, from which a brisk stream of water flows. This water, I am told by the miners, comes from a large body of water accumulated in the old mine. There is also a current of air here, which is said to come from the old mine likewise: Water $52\frac{1}{2}^{\circ}$; air close by the men (who have four candles) 57°.

g. *Same level,* 40 fathoms eastward of the shaft. A good current of air, and a stagnant pool in the bottom of the gallery four inches deep: this water 55°.

[We now come to the eastern part of the mine, which is worked at present; and it is to be observed that, in consequence of the declivity of the surface, the gallery in which the last observations were made, and which is reckoned as 74 fathoms below the surface, is only 64, at its eastern extremity, where it joins the other shaft. In our farther progress downwards, this latter numeration will be followed. This is the engine-shaft, and the water brought up by the pump is here 60°.]

h. 450 *Feet.* This gallery is driven only 22 fathoms, and has no communication but with the shaft. It has not been occupied or worked in for eighteen months. In its very inner extremity, there is a pool of water six inches deep, and several feet in diameter. This water 59°; air (quite still) in the same place, 60°.

i. 552 *Feet.* Gallery driven 40 fathoms east of the main shaft, and has no communication with any other. Four men have been constantly at work on the lode, in the inner end of this gallery, for the last twelve months, and have fired daily, during that period, from 8 to 12 charges of gunpowder in rending the lode, and its bounding walls of granite. There is some water trickling from the roof and sides which has accumulated so as to form a small pool in the bottom: this water 64°; air in the very inner extremity of the gallery 64°. The thermometer was left in the same place while two charges of gunpowder were fired, and upon being examined immediately afterwards, was found to have risen one degree, viz: to 65°.

k. In the bottom of this gallery there is much water, especially towards the shaft. In the vicinity of the shaft, air and water 62°.

l. 612 *Feet.* All the circumstances are here precisely the same as in the gallery above, in respect to air, humidity, and men at work, except that this is worked only 30 fathoms from the

shaft. The air here is not good, as the candles burn very badly. The greater part of the bottom of the level is covered with water. In the inner extremity the air and water are 64°; four fathoms from the end, water 63°; five fathoms from the end the water, which is in much greater quantity, being a foot deep, 62°; Ten fathoms from the shaft, air 62°.

The same experiment of blasting two charges of gunpowder was made in the inner end of this gallery, and the result was found to be precisely similar, viz. the elevation of the temperature of the air by one degree. No change, as might have been foreseen, was produced in the temperature of the water.

m. 678 *Feet.* One fathom below the last level is the reservoir for the water of the mine, (*the sump*): this is about two fathoms in diameter, and contains at present, water to the depth of two feet; it is boarded over at top. Air and water in this reservoir 64°.

5. Huel Vor. Tin mine. In killas.
Depth from the surface 948 feet.
Number of men employed underground 548.
Expenditure of candles per month 3000 lbs.
Expenditure of gunpowder ditto 3500 lbs.
Quantity of water discharged per day 1,692,660 gallons.
Temperature of this at the adit 67°.
Has been worked 12 years.

[I descended into this mine in the part most actively worked; the whole of my tract downwards thus lying over the deepest, and hottest part of the mine.]

July 31st, 1820.

a. Air in the shade, at the surface, 65°.

b. 210 *Feet* below the surface. The adit level. A current of air, 12 fathoms from the shaft, 63°. Midway between two shafts, named Pearce's and Gundry's; a good breeze from the latter; water dropping from the roof and forming stagnant pools; no work done here, but men pass through occasionally; air here 58°. water 57°. water as discharged at the mouth of the pump 67°; at some distance from the pump in the adit 66°.

c. 510 *Feet.* Level on the lode, communicating with the galleries above and below by *winses.* Forty fathoms east of the shaft, a gentle current of air near the upper wins; water dropping from the roof and covering the bottom of the gallery to the depth of eight inches. No work done here for years. Air 61°; water 60°.

d. 630 *Feet.* This gallery extends east of Pearce's shaft, 20 fathoms on the lode, and is then driven south through *the country* (killas) 30 more, when it terminates. It has no communication with any part of the mine, but with Pearce's shaft. That part of the gallery which is on the lode is rather damp, and contains

pools of water in the bottom; the cross-cut however is perfectly dry. No person has worked in this gallery for several years. The air in it is quite still. The temperature was very patiently noted. In the inner extremity of the cross-cut, air 61°; thermometer placed in an old shot hole in the rock, eight inches deep, 61°; buried in the loose slaty rubbish, 61°; in the mouth of the gallery, on the lode, air and water 63°.

e. 690 *Feet.* This level is very much worked out, and communicates freely with other parts of the mine. It joins Gundry's shaft at its eastern extremity. Some men are at work on the back, or top, of the level. There is a brisk streamlet of water here from the old mine (Huel Vreah) to the eastward; this water 64°; air here 65°.

f. 786 *Feet.* Level on the lode, driven east of Pearce's shaft 56 fathoms, and communicating with the gallery above by a *wins.* In this gallery there are nearly 40 men constantly at work, and the lode is very much worked out. The water dropping from the roof like a shower of rain. In the very inner extremity a large quartz *cross-course* has just been cut, through the open drusy cavities of which, a stream of water descends with considerable force. The air is here remarkably good, stream of water 70°; air in the same place 70°; in the same gallery, 20 fathoms nearer the shaft, and midway between the work-

ing of two *pairs*, the bottom covered with water, a gentle current of air; water 68°; air 67°.

g. *Same level.* In the eastern extremity of the gallery, much dropping of water from the roof and great accumulation of it in the gallery. This part of the mine has been long abandoned, and no workmen have been in the gallery for two years; air and water here 67°.

h. 846 *Feet.* This level is driven east of Pearce's shaft fifty fathoms; thirty men have been constantly at work in it for the last three months, who have exploded twenty-five to thirty charges of gunpowder, on an average, daily. There are very few men here to day. The lode is very hard, and the whole of the workmen do not extend the gallery more than from two to three fathoms per month. Notwithstanding the hardness of the lode, the gallery is very wet, the water dropping like rain from the roof, and lodging in the bottom. In the inner extremity of this gallery, air and water 67°, and the temperature of both is precisely the same at ten fathoms distance. Near the shaft the air is 64°.

i. 900 *Feet.* Gallery on the lode, driven east of Pearce's shaft 24 fathoms. This gallery is still wetter than those above it, the water rushing in large streams through the hollow parts of the lode, which consists of crystallized quartz and iron pyrites. Twenty four men employed here. Water of the descending streams

67°. The temperature of the air cannot be ascertained on account of the showers of water.

k. 948 *Feet.* This is the lowest level in the mine, and contains a great deal of water, which is of the temperature of 71°.

6. Dolcoath. Copper mine. In killas.

Height above the level of the sea about 300 feet.

Depth from the surface in 1819, 1386 feet; in 1822, 1428 feet.

Number of men employed under ground (1822) 800.

Expenditure of candles per month 6000 lbs.

Expenditure of gunpowder ditto 2600 lbs.

Quantity of water discharged by the pumps daily 535,173 gallons.

Temperature of pump water at the adit (1822), in the eastern part of the mine 72°; in the western ditto (much shallower) 64°.

Has been worked 20 years.

February 1819.

a. Air at the surface in the shade 47°.

b. 300 *Feet.* Air near the shaft 60°.

c. 540 *Feet.* Gallery, 25 fathoms east of the shaft, air 64°.

d. 930 *Feet.* Level on the lode. A strong current of air 62°.

e. 1140 *Feet.* Level on the lode, very dry. In the inner extremity men recently at work;

Air (very close) 74°; small puddle of water under foot, a few inches deep, 70°.

f. *Same level.* Another gallery, also very dry, air quite still, two men at work in the end, smell of recent explosion; air 71°.

g. *Same level.* Midway between the two shafts (30 fathoms distant) slight current of air; this 65°; water of a deep standing pool 62°.

h. 1260 *Feet.* Five fathoms from the engine shaft, in a cross-cut in which the water brought up by the pump runs; water 78°; air 76°.

i. *Same level.* A few fathoms distant from the place of last observation, there is a small stream of water which comes from some of the upper levels; there is also a gentle current of air coming from a shaft 35 fathoms distant; stream of water 65°; air 67°.

k. 1320 *Feet.* Inner extremity of a gallery where two men are at work, no current of air or water,—feels very close,—one explosion to-day, and there is now a strong smell of gunpowder. Small puddle of water in the bottom of the gallery. Air 76°, water 74°.

l. 1380 *Feet.* Lowest level in the mine. Inner extremity of the gallery, two men at work; place very close and hot; air seems a good deal contaminated, yet the candles burn well; air here 85°; water in the puddle underfoot 81°.

m. *Same level.* Eight fathoms from the end, air cooler and less close 81°; pool in the

bottom of the gallery, several feet in extent and a few inches deep; this water 76°.

n. 1386 *Feet.* Reservoir, or sump, a large cavity in which the lower end of the pump rests; a great deal of water in this, which is 84°.

7. Huel Abraham. Copper mine. In killas.
Depth under the surface in 1822, 1440 feet.
Number of men under ground 560.
Expenditure of candles per month 4800 lbs.
Expenditure of gunpowder ditto 1500 lbs.
Quantity of water discharged by the pumps daily 2,092,320 gallons.
Temperature of this as discharged into the adit 71°.

The water of this mine is drawn from the bottom about 160 fathoms, by one engine. It then runs through a level, about 150 fathoms in length, to another engine, by which it is drawn to the adit.

As Mr. Lean has published an account of the temperature of this mine, as taken in June 1815, in the Philosophical Magazine for 1818, I shall not repeat it here. He says, that at present (May 1822,) the air in the lowest level, which is 1440 feet under the surface, is 90°.

From the whole of the circumstances mentioned in the preceding journals, I shall now annex one general table, which may be con-

sidered as exhibiting a tolerably fair average of the temperature of the Cornish mines.

PART SECOND.

To persons unaccustomed to philosophical investigations it might perhaps appear, that the preceding documents and details must be at once admitted as unquestionable proofs of the augmented temperature of the earth beneath the surface; and that we have merely to look to the results of our tables, to fix its actual amount, its point of commencement below the surface, and its progressive increase as we descend. The members of this society, however, will be prepared for the consideration of several important circumstances, before these conclusions can be adopted.

The most important of these circumstances is the existence of artificial and extraneous sources of heat in mines. These sources are all, in Cornwall, either the direct or indirect consequence of the presence of the miner. Of the former class we have,—1, animal heat; 2, combustion of candles; 3, explosion of gunpowder; 4, friction and percussion: of the latter class, I shall have to notice the effect of mining in lengthening the atmospheric column.

In attempting to estimate the power of these causes it will be necessary to keep in mind the

MEAN RESULTS

OF THE

TEMPERATURE OF SIX MINES.

Depth in Feet.	Huel Neptune.		Botal-lack.		Little Bounds		Ding Dong.		Huel Vor.		Dol-coath.		Mean.	
	air.	*water*	*a.*	*w.*	*a.*	*w.*	*a.*	*w.*	*a.*	*w.*	*a.*	*w.*	*a.*	*w.*
120 to 150	57		59	57			55						57	57
150 - 200	56		60	58	54	54							57	56
200 - 250	56		61		57	55			60	57			58	56
250 - 300	56	55	61	59	57	59					60		58	58
300 - 350	58	54			55	55							57	55
350 - 400		57	66	62			55						60	59
400 - 450	60		66				56	54					61	54
450 - 500							60	59					60	59
500 - 550	67	67	67	68					61	60	64		65	65
550 - 600							63	63					63	63
600 - 650							62	63	61	63			62	63
650 - 700							64	64	65	64			65	64
700 - 750									67	65			67	65
750 - 800									68	68			68	68
800 - 850									66	66			66	66
850 - 900										68			*	68
900 - 950										71	62		62	71
950 - 1150											70	66	70	66
1150 - 1260											71	71	71	71
1260 - 1350											76	74	76	74
1350 - 1400											83	79	83	79

* Here there was a strong current of air.

nature of the operations of mining, and, more especially, the state of ventilation and moisture formerly described. It happens that almost all these extraneous sources of heat exist in the very innermost extremities of galleries which have only a very partial communication with the shafts and more airy parts of the mine, and in which, consequently, there is very little change of the air. On this account, and, moreover, because the walls of the galleries are not only very bad conductors of caloric, but are absolutely air-tight, the heat, from whatever cause arising, will be very slowly dispersed. The water, also, as it oozes from the lode in a state of extreme division, will seize and retain the heat, and in many cases, no doubt, will convey it to the inferior galleries by infiltration through the porous lode. The gazes extricated from the exploded gunpowder being of superior gravity to air, may, in like manner, be safely considered as carriers of temperature to the inferior parts of the mine. Of the actual power of all these various sources in raising the temperature of mines, I shall now proceed to make more particular inquiry.

1. By the experiments of Count Rumford and Mr. Dalton, on the heat evolved by different bodies during combustion, it appears that one pound of tallow is sufficient to melt about 107 lbs. of ice. But it is well known that the

quantity of caloric necessary to give fluidity to water is 140° of Farenheit: hence it follows that the same amount of caloric that melts a certain quantity of ice, will raise the temperature of an equal weight of water 140°. One pound of tallow, therefore, during combustion, will increase the temperature of 107 lbs. of water, or 13.3 gallons, (taking the pound of water to measure a pint, which is sufficiently correct for our purpose) 140°. This is equivalent to raising 1872 gallons 1°; 936 gallons 2°; 624 gallons 3°; 468 gallons 4°; 374 gallons 5°; and so on.*

2. Rude as the approximation to the truth may be in the preceding calculations, I find it much more difficult to come to any thing like a tangible conclusion in attempting to estimate the calorific power of gunpowder in mines. That it is very considerable, however, no one will doubt, who considers the situation and circumstances in which the powder is exploded. In one or two instances I have myself proved the heating power of this cause by direct experiment, as mentioned in a preceding part of this memoir. Gunpowder, during explosion, will increase the temperature of mines in two ways,—by communicating caloric to the sur-

* I shall hereafter apply these calculations to the phenomena of particular mines, when my reasons for adopting *water* as the measure of temperature will sufficiently appear.

rounding bodies like other combustibles, and by generating a large quantity of gas. The gazes generated have been ascertained by experiment to be 244 times the volume of the powder, supposing them to be, when evolved, of the same density as the atmospheric air; and, allowing for the effect of the heat generated at the time of explosion, it has been calculated that they will occupy 1000 times the space of the original powder. Now, admitting a pint of gunpowder to weigh somewhat more than 14 ounces, and allowing 60 pints to the cubic foot, we have thus 1000 cubic feet of gas for 50 lbs. of gunpowder, or 20 cubic feet for 1 lb.—taking into account the effect of rarefaction.

Gunpowder may, in the second place, be considered as a common combustible, and as generating heat in the ordinary manner, by the consumption of oxygen. Perhaps only about one fourth part of gunpowder is combustible, the remaining three fourths consisting of nitre, which merely furnishes the gazes that are evolved; and it is also certain that, in ordinary cases, a considerable part of that which is combustible is not inflamed. Taking into consideration, however, the effect of the great volume of gas evolved, the compression of the air, &c., I think it will not be beyond the truth to consider the whole produce of exploded gunpowder as equal to that resulting from the

combustion of an equal weight of charcoal. On this supposition the effect will be as follows:—according to Crawford and Dalton, the quantity of ice melted, in other words the quantity of water heated 140°, by the combustion of 1 lb. of charcoal, is 54 lbs. or about 7 gallons: this is equivalent to the elevation of 980 gallons 1°; 490 gallons 2°; 326 gallons 3°; 245 gallons 4°; and so on.

3. With the effect of the operation of friction and percussion in raising the temperature of bodies, we are all familiarly acquainted: the friction of two pieces of wood produces combustion: the hammering of iron renders it red hot: a single blow of a hammer on a copper coin will raise its temperature 20°. Now when we consider that the whole process of excavating mines is effected by iron tools, and by percussion and friction, either between these tools, or between them and the rock, we must admit this is a cause likely to produce a considerable quantity of heat in so confined a space as the gallery of a mine. Without taking any notice of the effect of the friction of the pumps, rods, &c., the incessant operation of rending the lode and rock, by the pick-axe and lever,—I shall, at present, only consider the probable influence of *boring* the rock for the reception of the gunpowder for blasting.

The most satisfactory experiments to ascertain the quantity of heat evolved in *boring*, are

those made by Count Rumford on the boring of cannon, the result of which (although as the pressure on the borer was equal to 10,000 lbs., of course there is nothing in the process of boring rocks that can properly be compared to it,) will be sufficient to show that a considerable evolution of caloric may be expected from that process in mines. In attempting to form some estimate of this in any one mine, we may allow half a pound of powder to every charge, which will make the number of holes bored exactly double the number of pounds of gunpowder expended. We may also allow three or four hours for completing each hole. A pound of powder will thus represent the effect of six hours continued boring; and 4 lbs. that of a whole day.

What may be the precise amount of heat evolved by this operation, I am, at present, quite unprepared to say; nor am I sure that I can form a conjecture respecting it, at all approximating to the truth. I should, however, be disposed to consider the action of four borers continued for 24 hours, as equal to the effect of the combustion of one pound of candles. By this supposition 16 lbs. of powder in the expenditure of a mine, will represent the effect of 1 lb. of tallow in combustion.

4. One of the most wonderful phenomena in nature, and one of the most striking instances

of divine wisdom, is the peculiarity of the living animal body to preserve the same degree of heat, whatever be the temperature of the medium in which it is placed. As, however, this mystery of vitality offers no exception to the general law that regulates the distribution of caloric, and as, in all natural circumstances, the temperature of the surrounding medium is below that of the human body, there must consequently be a constant transmission of heat from it to the air. In this point of view, then, every human body may be considered as a permanent focus of heat, diffusing it on all sides, from the commencement to the termination of life, in a quantity proportioned to its size. In the open air the influence of this source of caloric is quite imperceptible, and it is not very obvious in large and well ventilated apartments. In small and close apartments, however, or where many persons are crowded together, as in a theatre, the effect becomes very perceptible. For the same reason this cause must be very effective in the small air-tight gallery of a mine.

The living animal body raises the temperature of the air in two ways,—by contact with its exterior surface, and by respiration. The effect of the former mode is very inconsiderable, compared with the latter; although, perhaps, in the case of miners, who are very imperfectly clothed, it may be greater than in many other

classes of men. The effect of respiration in heating the air is very considerable indeed. It has been calculated by philosophers that an ordinary sized man receives into his lungs 48,000 cubic inches of air every hour, or 666 cubic feet per day. Now as the temperature of expired air is presumed to be nearly the same as that of the body (98°.), it will at once appear that this must be productive of a considerable quantity of caloric in the confined galleries of mines.

It is probable that the whole of the expired air is not raised to the temperature of the body; it is also certain that the mean temperature of air in mines is considerably above the mean of the climate: making allowances, then, for both these circumstances, it will perhaps not be far from the truth to suppose that the air respired by our miners receives an augmentation of only 30°. From these data we shall obtain the following results: the respiration of a single miner in 24 hours will raise the temperature of 19,980 cubic feet of air 1°; 9990 cubic feet 2°; 6660 cubic feet, 3°; 4995 cubic feet, 4°; and so on. Applied to the elevation of the temperature of water, the results will be, in the same time—48 gallons, raised 1°; 24 gallons, 2°; 16 gallons. 3°; 12 gallons, 4°; and so on. To this we may add 1-20th of the whole, for the effect of heat generated at the surface of the body.

5. To these direct sources of heat in mines I have now to add another, which, although quite unconnected with the operations of the miner, results from them. This is a cause which must be of universal operation, yet has not hitherto, as far as I know, been suspected to be at all concerned in the temperature of mines. What I allude to is the lessened capacity for caloric, of the air in mines, in consequence of its increased density. It has been long known that the temperature of the atmosphere decreases as we ascend in it; and it has been ascertained that the rate of decrease is about one degree of Farenheit for every 300 feet. The true cause of this decrement was not well known till lately; but it is now satisfactorily proved, I think, to be owing to the different capacity for heat which air has at different degrees of density.

As we ascend in the atmosphere, the density of the air decreases, and its capacity for heat increases proportionably. The converse of course is true. Of the operation of this principle in the free atmosphere, there can, I think, be no question; and it must be equally effective in the interior of all mines in which there is a free circulation of air. Every particle of air that descends into the mine will apparently acquire, and will exhibit, an increase of temperature equal to 1° for every 300 feet of its progress

downward; and the influence of this extrication of caloric in heating the interior of mines will not be the less real, in that the whole of it so extricated will be reabsorbed by the ascending current.

Were there no circulation of air in mines, the case would be very different, as the stagnant air must soon acquire the temperature of the medium in which it rested, or it would even acquire a lower temperature than this, from the tendency of the cold air of winter to descend, while the warm air of summer floated at top; and we are told by Mr. Leslie that this is the case in draw-wells and other subterranean cavities which are exposed to the air with open mouths, and in which no circulation takes place. For a similar reason, this source of heat can have only a very indirect influence in those parts of mines where there is little or no current of air, as in many of the working galleries; but in every other situation it must operate according to the depth of the mine, in the proportion mentioned.

In estimating the heating power of this source, it will not perhaps be right to allow one degree of increase for every 300 feet, in mines generally, as this is the maximum that can happen in any case; and as there are so many situations in which there is hardly any current, and where, consequently, the increase must be much less, perhaps it may be sufficient to allow 1° of increase over the whole of a mine, for a descent of 600 feet.

Let us now apply the results of these calculations to a single mine; and, in the first place, let us confine our attention to the temperature of the water, as both the actual quantity and heat of this, are much more readily estimated than those of the air. I take Huel Vor as an example.

The monthly expenditure of candles in this mine, as has been already mentioned, is 3000 lbs. that of gunpowder 3500 lbs.—the number of men employed underground 548, of which 180 are constantly there.

Supposing then that the whole of the extraneous and artificial caloric extricated in mines goes to the elevation of the temperature of the water (and this is allowing, of course, a vast deal more than the truth), the following will be the quantity of water, according to the foregoing calculations, raised every month in Huel Vor from the mean temperature of 52° to 67°, or 15°.

	Gallons.
3000 lbs. of candles (125 galls. per lb.)	375,000
3500 lbs. of gunpowder (63 galls. per lb.)	220,500
Friction and percussion - - - -	27,340
Bodies of 180 men - - - - - -	18,140
Total per month, - -	640,980

This is little more than one eightieth part of the water actually discharged at the adit, of the temperature of 67°.

In the above calculations I have made no allowance for the $1\frac{1}{2}^{\circ}$ of temperature, which, according to my previous admissions, ought to arise from the increased length of the atmospheric column; but I apprehend that some part of this must be allowed for the loss of temperature in the process of raising the water to the adit-level.

I ought to apologize to the society for submitting to its notice calculations so vague, and perhaps gratuitous, as the above. My reasons for doing so are, my anxiety to induce others to submit the subjects of my rude conjectures to the test of experiment, and my desire to have some tangible quantity to base my future reasonings on. Some of my calculations may be found erroneous, but I am convinced that, however erroneous, they afford ample proof of the inadequacy of all the artificial and extraneous sources of heat in mines, to account for the temperature indicated in them by the thermometer. Hence it follows, that the natural temperature of the earth in the mines of Cornwall, at the depths mentioned, must be very considerably above that of the mean of the climate. This conclusion is equally deducible from many facts which have been observed in mines. The most conclusive of these, is the high temperature of extensive collections of water in abandoned mines, or in parts of mines that have been long abandoned.

In many cases of this kind it is impossible to believe that the temperature can have been derived from any other source than the rocky walls of the cavity in which it is contained; and as these walls could not derive their temperature from any foreign source, the conclusion is equally in favour of the natural high temperature of the body of the earth at certain depths. An example of this kind is given (page 176, *k*,) in the account of Botallack mine, where the temperature of a large isolated collection of water is stated to be 62° at a depth of about 400 feet from the surface.

A still stronger instance, perhaps, in support of the same conclusion, is afforded by the details of the other submarine mine, Little Bounds (page 178). This mine was formerly worked to the depth of 500 feet. Of late years very little has been done, and the water has risen to within 40 fathoms of the adit, where it is kept stationary by the partial operation of the pumps. There is thus a permanent body of water extending from the depth of 300, to that of 500 feet below the surface, and to perhaps half that distance horizontally. This water, as discharged by the pumps (in 1822), is of the temperature of 56½°. It is needless to remark that the daily presence of half a dozen men, and the daily consumption of a couple of pounds of candles, and as many of gunpowder, could have

no perceptible effect in augmenting the temperature of the vast body of water that inundated the lower galleries of this mine. The inference seems here irresistible.

The temperature of 55° was found by Dr. Davy and myself in the water of the abandoned mines of Huel Bog and Huel Fortune.

These observations are very similar in their results to one mentioned by Daubuisson, in his work on the mines of Freyberg; and the general inference is greatly strengthened by this additional authority. The great mine of Kurschacht, worked to the depth of upwards of 1200 feet, had been in a great measure abandoned, and the water had consequently accumulated in it in vast quantity, being 360 feet deep, and extending horizontally 1800 feet. Daubuisson examined this mine in February, when the external air was of the temperature of 39°, and found the temperature of this subterranean lake to be 61°, which is about 10° above the mean temperature of Freyberg.

I am so much convinced, by experience, of the fallacy of observations made on the temperature of the *air* alone, of mines, that I am not sure if I can quote any single one of those recorded in my journals, as an unquestionable proof of the same truth. I think, however, I may be allowed to consider some of those made in the culs-de-sac of galleries long abandoned,

and extending to a great distance from the shaft, as affording approximations, at least, that may be depended on. Of this kind, I think, among the most satisfactory, may be mentioned those made in Little Bounds (see page 179 *f.* and 180 *n.*), and in Huel Vor, (page 188, *g. h.*). It will abundantly appear from many parts of my journals that we must rarely admit the temperature of either air or water in a state of motion in mines, as indicative of the natural temperature of any particular place.

I shall not now enter into any detail of observations made by others, in our own mines, or those in foreign countries. It may, however, be well just to state, in passing, that results very similar in kind have been obtained by Daubuisson in the mines of Saxony and Bretagne, Patrin in Siberia, Humboldt in South America, and lately by Mr. Bald, in the coal mines of the north of England.

In adopting the inevitable conclusion of the inadequacy of all the extraneous sources of temperature in mines, at present known to us, to account for the degree of heat found in them, and in the water discharged from them, it must be allowed that this extraneous temperature has a considerable effect in modifying the results observed in many parts of them. In proof of this I may refer to almost every page of my journals; and I mention it here chiefly for the

purpose of impressing the necessity of keeping the fact in view, in making future observations in mines, and in drawing inferences from those already made.

It is much more easy to be convinced of the fact of an increase of temperature, than to ascertain its precise amount, at any particular depth. Indeed, this part of our enquiry is extremely difficult, and for several very obvious reasons. The principal of these seem to be, 1. the impossibility in any part of a mine, of determining, with any thing like precision, the exact amount of temperature produced by the extraneous causes existing there: 2. the tendency of heated air to ascend, and of water, and perhaps the gazes from gunpowder, to descend, thereby carrying the temperature of one part of a mine into another: 3. the great discrepancy (perhaps a consequence of the two former causes,) between observations at similar depths, in the same mine, or in different mines, under circumstances apparently very similar. But although almost every page of my journals shews the difficulty of fixing the precise degree of temperature at particular depths, I think they prove irrefragably the progressive increase of this as we advance downwards.

Every fact observed by myself and others in the mines of Cornwall, and recorded by the gentlemen formerly mentioned, as observed in the

north of England, on the continent of Europe, and in America, goes to establish this conclusion; and it is satisfactory to find that all the observations hitherto recorded agree in their general results, as nearly as could be expected in a case involving so many disturbing causes; and perhaps it may be, upon the whole, as safe to take the mean of all the observations, good and bad, at nearly similar depths, as to attempt any nice classification of these, which, after all, in our ignorance of many essential points, might be less worthy of confidence than the other. Taking, then, the mean results of my observations on the different mines, as given in the last column of the table, it will be found that the mean rate of increase is about one degree for every 50 or 60 feet.

This result comes very near that drawn from the observations of Mr. Bald in the coal mines, and agrees with the deductions of my friend Mr. Fox, which have been presented to the Society. Admitting this as the true result of our observations, I should be disposed to deduct six or seven degrees from the extreme amount in our deepest mines, as attributable to the artificial and extraneous causes formerly detailed, and would thus fix the actual temperature of the solid matter of our earth (in Cornwall) at the depth of from 1300 to 1400 feet, at from 72° to 74° of Farenheit.

Perhaps one of the most conclusive and striking proofs of the increase of temperature as we recede from the surface of the earth, will be afforded by the relative temperature of the pump water of the same mines at different times. The only trials of this kind that have been made, to my knowledge, are the following: In 1819 the pump water of Huel Neptune, then of the depth of 540 feet, was 60°: in 1822, when the depth was 750 feet, it was 62°. In 1819 the water of Botallack, then 510 feet in depth, was 62°: in 1822, when the mine was 670 feet deep, it was 67°. No material change in the condition of these mines had taken place during the interval, except the increase of depth, to which the augmentation of the temperature could be attributed.

In making the preceding calculations respecting the rate of increase of temperature in mines according to their depths, it has been assumed that the increase commences immediately below the surface. We know however that this is not the case; a fact which is sufficiently proved by the copious and permanent springs in every country, which remain invariably of the mean temperature of the climate. This fact holds equally true in Cornwall, not only in the vicinity of mines, but in the shallower levels of mines themselves. At what precise point below the surface the augmentation of temperature com-

mences, I am unable to say, with any degree of confidence; but from a consideration of the influence of extraneous causes in modifying the temperature observed in the superior galleries of mines, and from some particular observations made by myself, I am disposed to place this point at about the depth of 200 feet from the surface.

In concluding this detail of positive proofs of the natural high temperature of the earth at certain depths, we might mention several circumstances observable in mines, which can hardly be explained on any other theory. For instance—if the natural temperature of the earth were not progressively higher as we recede from the surface, and if all the temperature observable in mines, above the mean of the climate, was owing to extraneous causes, we ought to find the lower galleries of shallow mines, or the upper galleries of any mines in which men were employed, of as high a temperature (or higher) as the lower galleries of deep mines. This ought especially to be the case in *dry* mines, in which the carriers of caloric upwards are much greater than the reverse ones. But the fact is very remote from this, as we invariably find that of two galleries which agree in every circumstance save that of depth, the deep one is much warmer than the shallow one. I speak here of *considerable* differences of depth; my journals sufficiently

show that in the case of slight differences, the reverse of what I have stated is frequently the fact.

In admitting the high temperature of the interior of the earth as a fact, it cannot be denied that very strong arguments can be brought against its probability. The most formidable objection to it appears to me to be the difficulty of accounting for the actual temperature of the very superficies of the earth, which is proved to be the same as the mean atmospheric temperature of each particular country. On a first view of the subject it would seem that, with so high a degree of temperature at so small a depth, the *very crust* of the earth, in place of being of the mean temperature of the external atmosphere only, ought to be the mean of this and of the internal temperature together.

Whether or not, in the event of there being an internal high temperature, the cooling power of the incumbent atmosphere, combined with the power of radiation of the earth's crust, be sufficient to cool down and keep at the degree of temperature observed near the earth's surface, I am unable of my own knowledge to say; but I am informed that this has lately been attempted to be proved by a French philosopher. Will the same principle of refrigeration explain the fact, of the temperature in mines being uninfluenced by difference of elevation above the

sea-level,—a fact, by the way, which seems not readily reconcileable with the doctrine of internal heat? The mines of Saxony, situated 1500 feet above the level of the sea, are of equal warmth with those of Cumberland and Cornwall, which are below the sea level. Will it also account for the very high temperature of the South American mines, as recorded by Humboldt, situated at the height of 7000 feet above the level of the sea? And will it accord with the well-known fact of the very low temperature of the water of the ocean, and of lakes, at very great depths?

It is not my intention on the present occasion to enter into any minute or elaborate inquiry respecting the probable origin of this internal heat, the existence of which seems to be now unquestionable. Before concluding this paper, I must, nevertheless, beg leave to make a few observations on the subject.

In proposing any theories for the explanation of this fact, it must always be borne in mind that we have not merely to account for the existence of a certain degree of temperature at a certain depth in the interior of the earth, but also for the constant renewal or supply of this temperature, to compensate for its incessant dissipation at the surface. It is certain that, however circumstances may modify the transmission of caloric, nothing can destroy its ten-

dency to produce an equilibrium of temperature in contiguous bodies. It is, therefore, obvious that, however high the temperature at which the earth might have been formed, it must have been, within a certain time, cooled down to the mean heat of the atmosphere in which it was placed. If then it be true that at certain moderate depths under the surface, the earth continues to be of a temperature very considerably above the mean of the atmosphere at its surface, the conclusion is irresistible, that there must even *now* exist some means of constantly renewing the supply of caloric in the interior of the earth.

In contemplating the subject in this point of view, there occur to me only the following modes of accounting for the facts, with any adherence to probability. 1. The existence of a permanent source of heat in the interior of the earth. This source we may conceive to be confined to the very centre of the globe; or we may conceive the caloric process to be diffused throughout the whole mass, or restricted to a nucleus of a greater or less radius,—or to an investing stratum of a determinate depth under the surface. 2. We may imagine, with my friend Mr. Fox, that there is a perpetual flow of aqueous vapour from the centrical parts of the earth to the surface, occasioning the high temperature of mines, by the evolution of the latent heat of the vapour on its condensation into water. 3. We may consider

the whole mass of the earth as possessing merely the mean temperature of the atmosphere on its surface, and the superior heat of mines as caused by extraneous and artificial causes, or by peculiarities of climate. Lastly, we may, in addition to the last supposition, conceive that the superior temperature of the tropical regions has acted, and continues to act, as a constant source of supply to the interior of the earth generally.

The two latter theories, which would derive the augmented temperature of the interior of the earth from known and obvious causes, would have greatly the advantage of the others, in a philosophical point of view, could they be brought to explain the facts which prove the increase of temperature in proportion to the depth.

Whatever may be the temperature of the earth at great depths, there does not appear much reason to doubt the general opinion entertained by meteorologists, that at certain moderate depths, the permanent temperature is precisely, or nearly, that of the mean atmospheric temperature at each particular place. It would also appear that this temperature is derived from the solar impressions on the surface. Perhaps we may admit 50 feet as the limit beyond which the impression of any individual season does not extend. I have already given it as my opinion, that no positive increase above

the mean of the climate can be detected above the depth of 200 feet. Admitting these points, we may, therefore, consider the earth as invested with a crust 100 or 150 feet thick, having a certain permanent temperature in every particular latitude, but varying in degree as this latitude is more or less remote from the equator. The particular temperature of this crust in every latitude (abstracting, for the present, the consideration of the heat of the bottom of the ocean) is, of course, that of the climate of each latitude. The mean of the whole has been calculated by Mr. Leslie to be 66,8°. of Farenheit; and this is the degree of heat which he considers the centrical parts of the earth ought to possess, on the supposition that the whole of this has been derived from the surface.

Admitting this calculation to be correct, it becomes a matter of inquiry (in the first place), at what depth in any particular climate we may expect to reach this mean temperature of 66,8°; whether we have reached it in any of those countries where mines are worked; and, if so, whether this degree of heat, combined with that from extraneous causes, will account for the actual temperature of mines?

Secondly, it may be a proper subject of inquiry, whether, on the supposition of the whole internal heat of the earth being derived from the surface, the amount of this heat generally,

or in particular places, may not be modified by the different conducting powers of the solid matters of which the earth is composed; by the relative extent of these matters; and by their mode and extent of communication with the surface. An ingenious friend of mine (Mr. John Barton) thinks it possible to account in this way for the high temperature of mines in northern climates,—conceiving that the heat of the equatorial regions may be conducted through the mass of the earth much faster than it can be carried off by the surface. The explanation is ingenious, but seems to me attended with many difficulties.

Before leaving the subject of the relative conducting powers of the matters which compose the earth, I think it may be worthy of consideration whether, admitting the great heat of the earth at great depths (whencesoever derived), some part of the high temperature of our mines may not be explained by the nature of the contents of the lodes. It is well known that metals are better conductors than stones. If this holds good in the state of oxydation and combination, in which the former are found in nature, (a circumstance which may be easily proved by experiment,) their power of influencing the temperature of mines becomes extremely probable, more especially as their inferior limit has never yet been traced.

If there be any truth in the general opinion of miners, that copper mines are warmer than tin mines, will this be in any way explained by the relative conducting powers of the two minerals? If there is any foundation for this notion, mines having large and rich lodes ought to be warmer than those with smaller. The nature of the *country* (rock) ought also to occasion a difference in the heat of mines. Granite, I apprehend, is a better conductor than killas: ought not a mine situated in the former, to be warmer than one in the latter? Shafts and galleries, also, cut through the *country*, ought to be colder than those driven on the lode. Mr. Fox is of opinion that this is actually the case; and some of my own observations seem to countenance the same idea; but I doubt whether we have any certain proof of the fact.

Note. I perceive that in the hurry of transcribing my remarks on the internal economy of the mines, in the first part of my paper, some errors have escaped my pen which I must here correct.

In page 164, it is intimated that one *pair* of men generally undertake the work of a particular gallery. It should have been observed, that only one *pair* can work in the extremity of a gallery, for there are in general, several *pairs*, *stoping*, or working horizontally, both over-head and under-foot, in each gallery.

In page 167, it is said that all the water of a mine finds its way to the *sump*. I should have said that all the water of the deepest level finds its way to the *sump*. The water from the upper levels is received into cisterns placed in different parts of the shaft, at the termination of each tier of pumps, from whence it is drawn to the adit.

J. F.

IX.—*Observations on the Hornblende Formation in the Parish of St. Clere.*

By The Rev. JOHN ROGERS,

MEMBER OF THE SOCIETY.

(Read October, 1818.)

Accompanied by a series of Specimens.

The Hornblende formation of St. Clere (near Liskeard) is principally confined to that elevated land called St. Clere Down. It extends about a mile from east to west, and about half a mile from north to south, and appears to run east and west, and to dip towards the south, or south west. On the south side of the Down, on the left of the road leading to Treworgy, we find large blocks of hornstone, and towards the south, and south west, the boundary hedge of the Down forms nearly the line of junction. In every other direction, the hornblende extends beyond the hedge, and nearly to the adjoining valley. The hornblende is generally coarse-grained, with

shining facets; but as it approaches its termination, it becomes more dull and fine-grained, and passes into hornblende-slate, accompanied by hornstone. The hornblende-slate is sometimes intimately combined with hornstone in the same specimen, and contains specks of pyrites. The hornstone is sometimes accompanied by what I take to be thallite, and has occasionally a thin coat of sulphate of lime. In one instance I found a large block of axinite and thallite, a little beyond the south-west junction. It may be observed that hornstone and hornblende-slate passing into clay-slate, are found throughout the whole line of junction, except towards the north-east, where I found no hornstone. In that direction, hornblende-slate, a kind of greenstone-slate, and clay-slate abounding with particles of mica, form the connecting chain of minerals from hornblende to granite. In this quarter likewise, in a field adjoining the vicarage garden towards the west, asbestus has been found in veins, in greenstone-slate; but the quarry in which it was found has been filled up for some years.

The mineral which I have called hornblende-slate graduates so imperceptibly into clay-slate, that I have hesitated which name to give to some of the specimens: it appears to be the slaty felspar rock of Jameson, and has been sometimes denominated purple killas.

I am inclined to think that, although the St. Clere Down formation is distinctly bounded, hornblende is also frequently to be found in other parts of this and the neighbouring parishes; indeed I believe it occurs much more frequently than has been generally supposed. At Cradock Mill is a quarry of hornblende-slate dipping south-east; and in the valley below Tremar, a large mass of rock, called Watertor, consists of dull, fine-grained hornblende, like that which has been mentioned before, as passing into hornblende-slate, towards the termination of the St. Clere formation. The river which passes through the valley runs over beds of stratified hornstone, dipping east. In the opposite direction, on Forsnooth Down, and again, towards the east, near Trevethy stone, hornblende and hornstone are found: at the former place blocks of hornstone bound the hornblende formation on the north and south. In a quarry south-west of Treworgy, I found a kind of decomposing greenstone; and a similar stone is raised near Ford, for mending the road from Liskeard to Callington. The clay-slate of Liskeard, which is admirably adapted for the purposes of building, appears to rest on this greenstone.

On the road from Liskeard to Plymouth, a quarter of a mile beyond Cartuther, a stone is quarried for the road, containing crystalline shoots of hornblende in felspar; decomposing

greenstone also occurs about a stone's-throw beyond the quarry.

Near Tregerla slate quarry, in the parish of Menheniot, ascending the hill towards Clikertor, the hornblende rock of St. Clere Down, and the same in a state of decomposition, occur in great abundance. At Deer-park, a quarter of a mile from the western extremity of Clikertor, I found a large boulder of hornblende, differing from that of Tregerla in containing specks of green indurated steatite, and from the Clikertor serpentine, in the greater abundance, and more shining appearance, of the hornblende.

The serpentine of Clikertor contains a much larger proportion of hornblende than the other serpentines of this county; and the hard variety seems to differ but little from the hornblende rock of Tregerla, except in containing particles of green indurated steatite.

I will take this opportunity of adding a few remarks, to those of my late respected friend the Rev. William Gregor, on the serpentine or hornblende formation of Clikertor.* This elevated land consists of a long ridge of rock of a serrated appearance,† apparently about a mile long, and a quarter of a mile broad, running east by south, and west by north. The serpen-

* See Mr. Gregor's paper on the Tremolite of Cornwall, in the Transactions of the Geological Society.

† It has been compared by some English officers who served in the last campaign in Spain, to the Sierras of that country.

tine terminates on every side, about two or three hundred yards from the brow of the hill, and passes generally into decomposing greenstone, and a kind of slate which may perhaps be called greenstone-slate. The serpentine decomposes externally on long exposure to the atmosphere, and in that state it bears a resemblance to the decomposing greenstone which surrounds the hill, and which has been mentioned in this paper as occurring at other places in the neighbourhood of St. Clere and Liskeard. I will finish this brief account of Clikertor with an analysis of the rock, which was made by my late friend the Rev. William Gregor, and which I have no doubt will be duly appreciated.

Silex - - - -	42,2
Oxide of Iron -	19,6
Magnesia - - -	16
Alumine - - -	2,2
Lime - - - -	,8
Water - - - -	11,4
	92,2

I will now briefly notice some other places where rocks of the hornblende formation occur. A quarry of hornblende is worked for mending the roads, about a quarter of a mile north-east of St. Mewan Church. The same stone is quarried for the turnpike road, on the terrace hill, north-west of Lostwithiel; and tough, greenish hornblende, of a crystalline structure,

is amongst the numerous mineralogical productions of Maudlin mine.

At the Blackhead, near St. Austell, greenstone and hornblende porphyry are found. Hornblende-slate and hornstone are met with on St. Neott's Down, towards Warleggan; and the former mineral is the intermediate substance between the hornblende rock, which occurs in great abundance in the Parish of Michaelstow, and the clay-slate into which the hornblende passes, towards St. Teath.

Large boulders of greenstone lie scattered in the neighbourhood of Tintagel, and some masses of this stone may be recognised in the ancient castle of King Arthur. Many large boulders of the same kind may be seen near the road from Bossiney to Davidstow.

I have generally found that hornblende occurs in the immediate neighbourhood of granite, and rests on the granite, as clay-slate often rests on the hornblende. The dark tough iron-stone of the miners is generally hornblende. The same mineral occurs, with blocks of hornstone, about a mile from Helston, on the Truro road; and the greater part of Helston is built of greenstone, from a quarry at the south-eastern extremity of the borough. The greenstone appears again at the old mine of Huel Pool; at Penrose; and on the beach between the Loe Bar and Portleven: I think it alternates with clay-slate.

At Treluswell, near Penryn, is a quarry of greenstone in which the hornblende is very distinct, and the formation seems to extend to Bellevue, on the road from Truro to Penryn, where large blocks of hornblende are seen near the side of the road.

It would be almost superfluous to mention the hornblende of the peninsula of West Penwith. It is well known to the members of our Society that this mineral, alternating with clay-slate, nearly encircles the granite formation in that interesting geological district.

I will conclude these remarks by observing that the only way to obtain, and perpetuate, an accurate knowledge of the geology of this county, is by forming an extensive collection of rock specimens, with their several localities accurately marked.* It was with a view of affording some small assistance towards the accomplishment of this object, that the specimens which accompany this paper were collected, and I shall be happy if what is now submitted to the Society shall in any degree contribute to supply those great desiderata, an accurate knowledge of Cornish rocks, and a correct and distinct nomenclature.

* The specimens which accompanied this paper are deposited in the cabinets of the society, and may be discovered by reference to the catalogue.

X.—*On the Phenomena of Intersected Lodes, and the legitimate Inferences which may be drawn from them.*

By JOHN HAWKINS, Esq. F.R.S. &c.

HONORARY MEMBER OF THE SOCIETY.

(Read October, 1820.)

Whatever may have been the nature of that power which has occasioned those fissures in the strata which we call lodes; it appears to have acted at various intervals of time; but to have exerted itself at the same period, with few exceptions, in a uniform direction.

The immediate effect of this power, thus set in action, was a separation of the strata in a linear direction, and a subsidence or displacement of one of the sides of the fissure.

There are various and unequivocal proofs of this partial subsidence, in the strata of every mining country, and some of these are very striking: I shall point out a few which best deserve attention. First; wherever the strata

are not perfectly homogeneous, the corresponding beds are invariably found at different levels, on the two opposite walls of the lode. Secondly; the two segments* of a lode which has been severed or intersected, are generally found more or less remote from each other, and the ends of the two segments are observed, in numerous instances, not to correspond with each other at the same level, either in respect to breadth, or the nature of their contents.

But the most general and unequivocal proof of this partial subsidence of the strata, is derived from a circumstance of distinction, first noticed by Werner, that whereas in simple fissures, the two sides, whatever may be the variation in their distance, observe a parallelism and conformity, or, as we should say, tally with each other; those of a lode, on the contrary, vary most capriciously in these respects, and are usually in opposition; concavity facing concavity, and convexity pointing to convexity. This perhaps is the reason why so many hollows are found in the centre of lodes, for as the solid contents of most have been evidently formed by successive crystallized depositions on the two walls, the progress of their formation must have been arrested, whenever the two opposite series were in contact.

* The more extensive signification which I give to this word seems to be justified, by the use of the word *fragment*.

I have noticed, in another place, the subsidence which is occasioned by a slide, or a slip of the beds of the strata over each other; and described the disorder which usually accompanies it, in respect to the relative position of the shifted parts of the lodes thus separated. The intersections of the strata have produced indications of another kind of subsidence, which is by far more common, and, in as much as it is connected with the origin of lodes, of more general interest.

These intersections and subsidences must have taken place at various intervals, and in opposite directions; there are even proofs of their repetition in the same direction: we have an example of this at Botallack, where two distinct lodes occupy the space between the two walls.

Of the extent of these lines of intersection, the art of mining has not yet supplied us with any very accurate information. It is certainly greater than it is generally conceived to be, for I have not yet heard of a well authenticated instance of the absolute termination of a lode. If their depth too bears any just proportion to their length on the surface, we cannot be supposed to have reached it in any instance; we shall therefore feel the less difficulty in accounting for what is called the heave of an intersected lode: for although the subsidence of one segment of the strata in this direction, is not what we

should expect to take place, if it had been guided solely by the law of gravity; yet what is a heave even of forty or fifty fathoms, when compared with a subsidence of many miles in extent, and of a proportional depth?

The direction of these heaves, a matter of such great importance to miners, is an object of no less interest to the geologist; but although, in Cornwall, the lost segment of a lode is found most commonly to the right of the intersection, or, in the language of the miner, *is heaved to the right*; yet, if the parts correspond pretty well at the same level, it is not easy to say which of the two is the moved segment, and which the unmoved one. The solution however of this problem ought in all instances to be attempted.*

In Saxony, whether the correspondent segment be found again to the right or to the left of the intersection, the lode is constantly observed to be heaved *on the side of the obtuser angle*; and this, as far as I can learn, is generally the case in Cornwall.

In Cornwall too, the more obtuse that angle is, the greater the heave is observed to be: I mean in most instances; for the length of the heave is not always governed by this law, and some of the greatest heaves seem to be inde-

* In countries where the underlie of the lodes is very great, the subsidence is generally observed to be on the hanging side.

pendent of it. In general it may be said, that the heaves are greater in Cornwall, than they are in other mining countries. Some extraordinary instances of their length are mentioned by Mr. Thomas.

Of the very numerous examples of intersected lodes in this county, one of the most instructive is that which I shall now submit to the notice of this Society.

The great copper lode at Carharack in Gwennap, the average breadth of which is about 8 feet, has a direction nearly east and west by the compass, and underlies to the north at an average inclination of two feet in a fathom. The upper strata through which it runs, are of killas; the lower, of growan; the latter rising nearer to the surface, the farther the lode is pursued to the westward, until the former disappears.

It is at some distance from this point, that the lode, in the small space of about forty fathoms, or less, has suffered two intersections, and in each instance has been heaved to an extraordinary distance; in one instance to the right, and in the other to the left.

The easternmost of these intersections has been occasioned by a flookan, called Stevens's flookan, which, running north-east and south-west, heaves the lode several fathoms to the left: the westernmost is likewise occasioned by a flookan, called Huel Damsel flookan, which,

running nearly at right angles to the other, moves the lode twenty-one fathoms to the right.

The first of these heaves was observed to be greater near the surface than below, and it diminished from eleven to nine fathoms; not, as is here supposed, because the underlie of the flookan (which was about nine inches in a fathom to the south-east) increased as it grew deeper, but because the western segment underlied faster. The second amounted, as I have already mentioned, to twenty-one fathoms. The annexed plan of these double and contradictory heaves (see Plate IV. fig. 1.) will shew the relative position of the three segments of the lode which has been thus divided; at the same time it proves how much more general in its application, the Saxon rule for finding the lost segment is, than the Cornish one; the lode being in each of these instances moved on the side of the greater angle.

The middle or insulated segment preserved the same direction as that of the eastern, but the western deviated from it in a slight degree.

The average breadth of Huel Damsel flookan was from two to three feet: I am unable to state any particulars of its underlie.

The ends of the lode which were in contact with the other flookan, were said to be ragged, as if they had been torn open, and pieces of the lode were found intermixed with its substance.

Fig. 1.

CARHARACK.

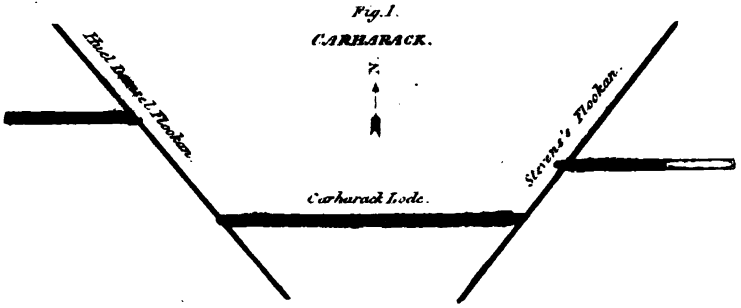


Fig. 2. Down-slide.

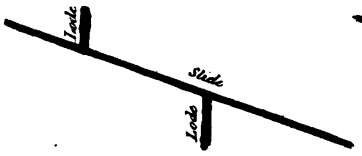


Fig. 3. Up-slide

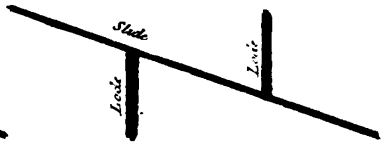
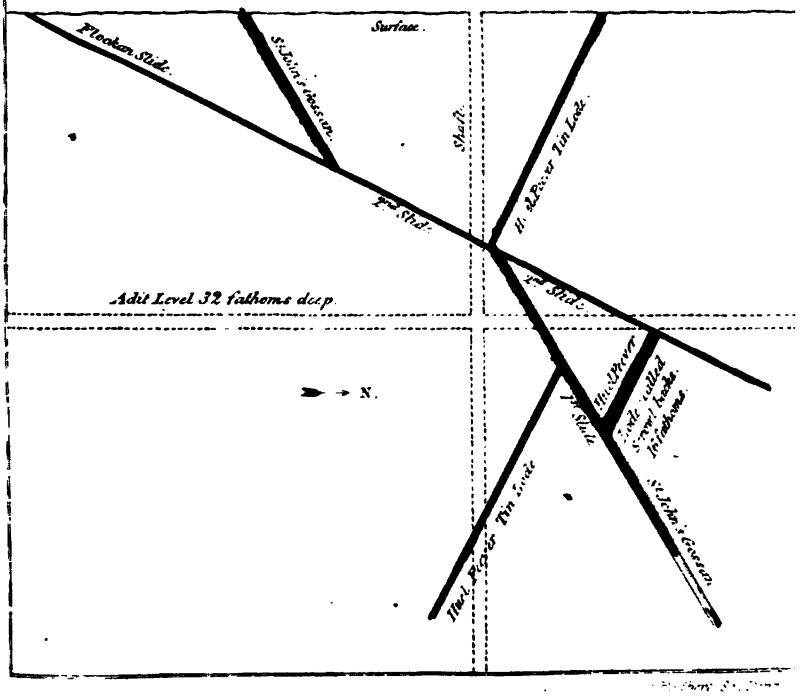


Fig. 4.

HUEL PREVER.

Section.



Published by T. Vigurs. Penzance. 1822.

I cannot close this account of these two remarkable intersections and heaves, without acknowledging the authority for my information. I procured these particulars from Mr. Joseph Morcom, one of the most intelligent directors of mines that it has been my good fortune to meet with in this county. So many years, however, have since elapsed, that they are probably at this time but little known, or may be forgotten. Nor can I dismiss the subject without mentioning another remarkable phenomenon which distinguishes the same lode. About thirty years ago, there was discovered in it, at the depth of seventy or eighty fathoms, a quantity of bitumen, dispersed through the substance of the lode and the contiguous growan.

XI.—*On the Intersection of Lodes in the direction of their Dip or Underlie.*

By JOHN HAWKINS, Esq. F.R.S. &c.

HONORARY MEMBER OF THE SOCIETY.

(Read October, 1820.)

In every mining district throughout Europe, the veins, in respect to their course or line of bearing, are observed to cross each other in various directions; those of more recent formation passing through the more ancient, and in most instances removing the separated parts to some distance from each other. In no country, I believe, are the instances of this interruption more frequent than in Cornwall, and in no country are they accompanied with the marks of so much disorder.

It is in Cornwall too, that the veins or lodes are subject, not merely to the usual sort of interruption here spoken of, but to others, which characterize very strongly the nature of those convulsions which have occasioned them. I

allude here more particularly to *the intersection of their underlie.*

When a lode is severed in this direction, its two segments, which likewise are always found at some distance asunder, are said by the miner to be *started by a slide*; and a distinction is very properly made between a gossan-slide and a flookan-slide; the former being occasioned by a regular lode, the latter by a thin layer or vein of clay, which divides the beds of the killas.

The angle of incidence is, of course, very different in the two cases here distinguished; the underlie of the gossan being not less vertical in most instances, than that of the lode which it crosses; while the position of the flookan is usually as horizontal as that of the strata between which it is interposed.

It is easy to conceive that the gossan-slide can only take place when the two lodes which are thus brought into collision, are either parallel, or differ but a few degrees in their course or bearing; and consequently that the flookan-slide must be by far the most common.

The gossan-slide too, being itself the effect of a regular lode-fissure, can occasion this disorder only in lodes of a more ancient formation; its influence is therefore confined to the tin-lodes; while both gossan-lodes and tin-lodes are alike intersected and started by flookan-slides.

As there are two modes in which a lode may be heaved by another which intersects it in its course or bearing; so there are two modes in which it may be started in the direction of its underlie, by an intersecting gossan or flookan; one of which is called an *up-slide*, and the other, a *down-slide*. It will be seen by the diagrams which represent the two cases here mentioned, (see Plate IV. fig 2. and 3.) that these terms, although easy and obvious in their practical application, convey nevertheless, like many others in common use, rather a false idea of the nature of what they designate; for the miner in this, as in other instances, refers every new occurrence to his own situation, or rather to the progress of his operations below ground; and the lode before him is said to be heaved to the right, in reference to himself as he advances; or to be started by a slide, up, or down, to the north, or to the south, to the right, or to the left, according to the situation in which he finds the lower segment. The same ambiguity of meaning is conspicuous in his account of the inclination of the lode to the horizon; and a lode which is represented as under-lying *fast* to the north, or to the south, will be found, upon examination, to deviate but a few degrees from the plane of the horizon.

It is singular that Borlase, who, in his short account of the Cornish lodes, has omitted all

mention of their mutual intersections in the line of their course or bearing, and the heaves which are thus occasioned; has nevertheless taken some notice of the circumstance which we are now considering; although it is by no means of such frequent occurrence.

"In a mine" says he "called the North Downs, "when they find the tin lode quite worked out "at the bottom, and no farther appearance of a "lode; instead of sinking any farther, they drive "across, and at a small distance, find a part of "the same natured tin lode as they worked be-"fore, and in the same direction. When the "parts of the same lode are found thus separated "from each other, the tinners' expression is, "that the lode is heaved or started." He adds, "In the lands of Kelluz in St. Erth, the lode is "started to the north twenty-five fathoms." This is all that he says to the purpose, on the subject of so remarkable a phenomenon; for his attempts to illustrate it, and account for it, are wholly unsatisfactory.

But Borlase is not the first writer who has noticed the starting of lodes in their underlie. In Hutchinson's Observations, which were made here in the year 1706, I find a very clear definition of it in the following words:—"So like-"wise a fissure running, suppose east and west, "that passes down in a perpendicular through "several strata, frequently terminates, and abuts

"upon the solid surface of a stratum, where, "mining horizontally upon the surface of that "stratum, either north or south, at some dis-"tance, the miners meet with another fissure, "running on the same point east and west." Page 315—6. He explains this shortly afterwards by a diagram, and calls it "a starting of the fissure." Page 317.

Upon this subject, however, more full information is given by a later writer, who perhaps had much better opportunities for collecting information. This writer (Pryce) distinguishes the two cases of a gossan and a flookan slide; the first occasioned by the meeting of two lodes of different formation in their underlie; the second by a minute fissure filled with clay, which intersects a lode in the same direction. He omits nevertheless some circumstances of importance; for instance, the great underlie of the flookan; states some incorrectly; such as, the relation of the start to the bigness of the gossan; and like his two predecessors, strains every fact to meet a preconceived hypothesis. To make amends for all his tautology and obscurity, we are presented with the first actual representation of a slide, in the instance of the Pink mine; where the tin-lode is started successively by three gossan-lodes, which meet it nearly at right angles.

Although the three writers whom I have just quoted, agree in ascribing the starting of lodes to a partial subsidence of the killas strata; yet neither of them seems to have been aware of the very different circumstances under which this disorder occurs, in the case of an up-slide, and in that of a down-slide; and consequently of the difficulty of accounting for each, by the same inductive process of reasoning. As both these cases occur in the mine called Huel Peever, nothing can be more interesting and instructive than an accurate statement of the facts which have been observed there; and although these have been already very well described by Mr. John Williams, in the fourth volume of the Transactions of another Society, yet, as the account which I now submit to the present assembly has been compiled from notes * which were collected at a much earlier period, through the medium of one of our most intelligent practical miners †; and as some advantage is gained by a comparison of evidence; I am induced to think that the information which it conveys, although it be merely corroborative of the principal facts, will not be considered as superfluous.

The mine called Huel Peever, is situated in a district of killas, the surface of which is not

* In the form of answers to a series of questions adapted to this particular case.

† The late Captain Thomas Gundry of St. Hillary.

particularly uneven. Here are two parallel lodes running east and west, and dipping towards each other, under different degrees of inclination to the horizon. The northern is a tin-lode; the southern, called St. John's gossan, a copper-lode. They are consequently referable to two distinct periods of formation; and hence it is, that at the point of their coincidence, the more recent of these, which is the copper-lode, passes through the tin-lode, which is the older; and a partial subsidence has taken place of one of the segments of the latter; the upper segment being removed to a much lower level. This is the case to which our miners have applied the name of an *up-slide*, and not improperly, if it be considered only in reference to the progress of their working, and not meant to designate the nature of this disturbance, which is a simple subsidence; the superior strata, after having been divided by a fissure from the inferior, being enabled to settle in a lower position.

If lodes were originally fissures occasioned chiefly by the uneven resistance of the strata to the pressure of gravity, as Werner supposes; a shifting of the opposite sides of the fissure must necessarily have been the result of this subsidence in every instance; and the hanging side, or back of the lode, will generally be found,

as it here is in St. John's gossan, removed to a lower level.

At a period subsequent to this, another disintegration of the strata, under very different circumstances, appears to have taken place here; both these converging lodes being intersected by a flookan, which underlying twelve feet in five* towards the south-east, has caused a displacement of the strata in a contrary direction; the superincumbent beds being here removed to a higher level. The correspondent segments of the two lodes, in this instance, are started to the distance of 18 fathoms from each other; whereas in the first mentioned, their removal did not amount to half that interval. The subjoined section will render this example of compound dislocation more intelligible. (See Plate IV. fig. 4.)

Of the violence with which this last-mentioned change was effected at Huel Peever, some notion may be formed by a circumstance which I shall now mention. The middle segment of Huel Peever tin-lode was found to be much wider than the two others, and in a state of great disorder; and some fragments of the upper segment were carried off with the slide, or, more correctly speaking, strewed along the line of removal, to the distance of several feet. Traces of this disorder were likewise observed

* Mr. Williams says 14 feet in every fathom.

at the top of the lowest segment, occasioned by the gossan-lode. The disorder of the middle segment has evidently resulted from the enlargement of this part of the lode, and its enlargement must be attributed to a subsidence of the lower wall, when the strata had acquired so much liberty to settle in this direction.

The general width of Huel Peever tin-lode was from eight to ten feet. The slide carried a flookan or layer of clay, about two or three inches wide; and had two or three feet of soft ground contiguous to it.

I have now to mention a revolution which, at a period still later, has caused another transposition of the strata, together with all their contents, and created still greater confusion. The adit-level called Hattam's end, here represented in the transverse section of the lodes, at the depth of 32 fathoms, was driven on a cross course, which has heaved both lodes and slides forty fathoms to the north. The direction of this cross-course was nearly at right angles to that of the lodes, and its underlie two feet and half, or less, in a fathom. Mr. Williams has described a second cross course at a short distance to the west of this, which again has heaved the lodes a few fathoms still farther in the same direction; besides another flookan slide which has started the lower segment of Huel Peever tin-lode. This slide is less

horizontal than the other, and the start which it has occasioned is not so considerable. Is it because the angle of incidence in this case is not so great, that the segments are moved to so short a distance from each other? (for the heaves seem to follow this law,) or does it arise from the greater resistance which the strata present in this direction? (the converse of which seems to be exemplified in the great start occasioned by the superior and more horizontal flookan,) for we see both here and in the Pink mine, that the starts diminish in length, as they lie deeper.

Having adverted to the cause of these disturbances, prematurely perhaps, considering our imperfect acquaintance with them; I must confess that the two opposite cases into which these slides may be resolved, plainly denote some cause more complicated than I can at present form a just conception of.

The down-slides are said to be the most frequent in the neighbourhood of Huel Peever; that is, about Redruth and Gwennap: but in St. Agnes, the lodes are generally started upward. Their frequency too, in that parish, is attributed by some, to the very inclined position of the killas strata.

It is very remarkable that at Ding Dong, in Madron, the tin-lode is both heaved and started by the cutters and clefts of the granite through which it passes.

XII.—*On the Geology of the Land's-end District.*

By JOHN FORBES, M.D.

HONORARY MEMBER, AND LATE SECRETARY, OF THE SOCIETY.

(Read September, 1819.)

I INTEND, in this paper, to give some account of the physical structure of all that portion of Cornwall situated to the westward of a line drawn from the estuary of Hayle on the north coast, to Cuddan point on the south, which I have here called, for the sake of distinction, the Land's-end district. In doing this, I shall state nothing as a fact, which I have not myself verified by personal examination, and all my observations will be illustrated by specimens deposited in the cabinet.

This portion of the county is about thirteen miles long from east to west, and five or six miles broad from north to south, and contains by superficial admeasurement, about 54,000 statute acres.

Generally speaking, the surface of this part of the country is very uneven; being much broken by hills and vallies, more remarkable however, for their number and picturesqueness, than for their magnitude. The highest hill is Castle Endinas, in the parish of Ludgvan; the exact height of which, above the level of the sea, I am unable to state. The following are some of the admeasurements in feet, above the level of the sea, given by Col. Mudge and Dr. Berger:—Burian church, 519; Sennen church, 391; St. Just church, 404; Carn Galva, 623; Tower on St. Michael's Mount, 231; Cape Cornwall, 229; Land's-end, 50 or 60.

The whole line of coast, with the exception of some part of the western shores of Mount's Bay, and a few small bays of less consequence, is uniformly and remarkably precipitous,—offering throughout its whole extent, some of the finest cliff-scenery in the island. This character of the coast is particularly favourable to the geologist, laying open to him, in every direction, by the most splendid natural sections, the exact structure and relations of the rocks of which the country is composed. Nor is the physiognomy of the rocks in the interior less remarkable than on the coast. On every hill the granite is seen protruding in the most fantastic forms from the scanty and imperfect covering of soil. These, under the name of Tors and

Carns, have often engaged the attention of the antiquary and geologist,—as they must ever continue to attract the notice of the tourist.

In noticing the character of the surface, we must not forget St. Michael's Mount, one of the most remarkable, and most beautiful objects of natural scenery in the world.

The small extent of this district, and its peninsular character, precludes the existence of rivers of any magnitude: its varied and uneven surface, however, gives it a great profusion of small streams and rivulets, which add greatly to its value as well as beauty. It must be confessed, however, that on account of the peculiar value of our streams, their beauty is too often destroyed by the operations of streaming, and of the stamping mill. Besides the streams, this district is remarkably rich in excellent springs of water; but, with the exception perhaps of two or three, it possesses none remarkable for their mineral impregnations, or medicinal virtues.

Although the alluvial covering is extremely scanty on the higher spots of this district; yet in the plains, and in many of the vallies, the deposition is considerable, reaching in some places to a height of 20 or 30 feet above the solid rock.

The nature of this covering varies, generally speaking, with that of the subjacent rock; being, in the killas or slate districts, of a soft clayey

character, with a trifling intermixture of boulders or rolled stones; and in the granite districts, of a sandy gravelly character, with a large intermixture of the undecayed water-worn fragments of the granite. Some of these fragments are very large, and are found in many parts of the country, hundreds of feet above the present level of the sea.

I have said that, *in general,* the soil, and the rolled masses of stone contained in it, correspond with the nature of the subjacent rock; it is nevertheless true that at the points of junction of two rocks of different nature, as for example of granite and killas, the *boulders and soil* derived from one rock, are generally spread to some distance over the other. All around the coasts where these junctions take place, there is a belt of soil of equivocal character, to which the farmers in some parts of the county, give the name of *flux-country*; but it is generally found that it is *granitic* or *growany* soil that encroaches on the killas territory, and not the killas on the granite; this is easily accounted for by the fact of the granite almost always lying higher than the killas; a circumstance which will necessarily give the direction we have noticed to any bodies rolling on its surface.

The extent of these encroachments is, however, remarkably small, for wherever we see a large boulder of granite, or of greenstone, we

may be pretty sure that, if not beneath our feet, rocks of this kind are near at hand; and with equal assurance may we calculate on there being a junction of the slate and granite near us, when we observe fragments of *shorl-rock* in the soil;—a variety of rock which, as will hereafter be shown, is scarcely found, except in veins traversing these two rocks at their junction. Under the head of alluvial deposits, *must* also be classed the *sands* that cover many parts of the coast; and the *stream-works*. As these, however, have been treated of by other members, I shall pass them by at present.

The geological structure of this district may be said to be very simple, in as much as it includes but a small number of rocks, and as the various relations of these to each other are very similar, and readily discoverable. The main body of the district is *granite*,—a rock which indeed constitutes nine tenths of the whole. On the edges of the granite, in different points of the coast, reposes a certain assemblage of rocks, which, from their intimate relations, obviously constitute *one formation*. These rocks I shall take the liberty of naming in this paper the *Slate formation;* a term which answers exactly to the *killas country* of the miners and farmers in this part of the county. Generally speaking then, this district consists of two, and only two formations; the *Granite formation*, and the *Slate*

formation; very dissimilar in appearance, and indeed very distinct in all their characters; although, as will hereafter be more particularly noticed, in all probability of contemporaneous origin.

The respective limits of these two formations are accurately laid down on the map, (see Plate V.) from which it appears that nearly the whole of this district is *granite;* the *slate formation* forming merely a narrow slip or border, which is continuous on the more eastern limits, but broken into patches on the western shores. The continuous or eastern border commences at the village of Mousehole, in Mount's Bay, and terminates near Polmear, on the north coast; the line of junction with the granite passing through, or in the vicinity of, the following places, viz. Paul church, Nancothan, Trengwainton, Madron church, Trevayler, Trassow, Tregendra, Rejaren, Trevethoe, Carbis, Tregenna, Helesvear, Trowan, Trevalgen, Zennor church, Treen, and Polmear. The patches of this formation on the western shores are three:—one near the village of Rosemodris; another in Whitsand Bay; and a third and more important one, lining the coast from Porth Just, near Cape Cornwall, to Pendeen Cove.

I shall now proceed to give some account of the rocks constituting these formations.

drusy cavities, and in large crystals, in different parts of the coasts of Zennor and Burian.

With regard to the structure of the granite formation on the great scale, I have to observe, that it no where exhibits any appearance of regular stratification, notwithstanding the assertions of De Luc, and other theorists, to the contrary. It is, indeed, true, that it occasionally shows an irregular tabular structure, or rather a conformation somewhat similar to that observable in some of the trap rocks, called by some the *seamed structure;* and this is well seen on the eastern base of St. Michael's Mount; in the rocks west of Cape Cornwall, and in some of the quarries in the Parishes of St. Just and Burian; but a very slight inspection shews these appearances to bear no relation to true stratification. Indeed, in almost every case, I have been forced to consider it rather as an example of one of the modes in which this rock disintegrates, than as an essential and original quality of structure. Its occurring chiefly on the surfaces that are covered with a bed of alluvial soil;—its disappearing at the depth of a few yards;—and its not being found on those parts of the coast where the slate immediately reposes on the granite,—are sufficient proofs of the truth of this opinion. The tendency of granite to assume this adventitious tabular structure in the progress of decomposition, is stri-

kingly exemplified in the picturesque remains of St. Michael's Mount, and in the hoary Carns that crest the summits of all the hills in this part of the country.

OF THE SLATE FORMATION.

This formation is much more complicated than the last, and affords much greater scope for geological research. It comprehends, as far as I have been able to ascertain, five distinct rocks. These are clay-slate, hornblende-rock, greenstone, compact felspar, and slaty felspar. The three first of these are so well known; have such distinctive characters, and are of such general occurrence, that we are not very likely to be mistaken in discriminating, and giving them their proper appellation. Of the correctness of application of the two last terms I am less certain: from the peculiarity of their characters and their distinct nature, however, I am sure that, whether rightly named or not, they are as well entitled to appropriate appellations as any rocks can be.

By felspar-rock, I mean a rock of small granular structure, consisting, apparently, principally, or almost wholly, of felspar. By slaty felspar, I mean a rock apparently of the same composition, or only with the addition of a very small portion of mica, with a distinct slaty fracture.

These five rocks, constituting the assemblage to which I have given the name of the *slate formation*, occur in beds of various magnitude, alternating with each other; but with one very small exception, I have uniformly found the *slaty felspar rock* in immediate contact with the granite; and I think it not improbable that, in proportion as we recede from this central rock, we shall find the slaty felspar become less frequent, and be finally superseded by some of the varieties of clay-slate. Thus in the whole range of the killas country, or slate formation, that borders the shores of Burian, St. Just, Zennor, Towednack, and St. Ives Parishes, there is scarcely a vestige of clay-slate; and, in the eastern border, the first appearance of it which has occurred to me, is in the neighbourhood of Penzance, at least one mile from the granite; the only slaty rock in the intervening space being the slaty felspar. Proceeding to the eastward, as we leave the granite behind, the slaty felspar entirely disappears, and clay-slate becomes the prevailing rock. But I must forbear entering on these more general observations, until I have described the various individual phenomena exhibited by the different parts of the district where this formation is found. Beginning with the more simple, I shall first notice the patch at Rosemodris in Burian.

1. *Rosemodris.*

This portion of the slate formation extends from east to west, constituting the sea cliff, for the space of three quarters of a mile; and runs into the country to the medium distance of a quarter of a mile. It consists almost entirely of the slaty felspar rock. It is, in fact, only one bed; and, with the exception of veins of granite, and some imbedded masses of quartz, and a few of garnet rock, contains no foreign mineral, and exhibits little variety of structure. Although the individual strata are not very distinct, the lines of stratification are very obvious. From various observations, in different parts, it appears that this bed has a *direction* nearly north and south, and consequently dips east,—the angle of inclination being from 20° to 30°.

The junction of this bed with the granite is remarkably well seen in the cliff, on its western extremity: at its eastern extremity it terminates more abruptly, the line of junction being nearly vertical. The whole of this patch of rock seems included in a partial hollow of the subjacent granite.

At the western junction of these rocks, the granite is beautifully traversed by a great many veins of shorl-rock, which occasionally exhibit very distinct crystals of shorl. These veins run in various directions, and in several points

intersect each other, without shewing any *shift* or *heave*. They vary in width from a few inches to two feet. They cannot be traced into the slaty rock. At this place I could find no veins of granite traversing the superincumbent rock; but near the union on the eastern extremity, the slate is traversed in all directions by veins of considerable magnitude, some of which intersect each other.

2. *Whitsand Bay.*

The next point of the coast, proceeding westward, where this formation makes its appearance, is at the western extremity of Whitsand Bay, near the Land's-end. At this place there is a small patch of the slaty felspar rock, laid bare at low water, of about one hundred yards in breadth. It is seen in immediate contact with the granite; and the two rocks are so intermixed, as to baffle the explanation of every theory but that of a contemporaneous formation. Large veins of granite, varying in the character of its constituent parts, traverse the slate in all directions, while patches, if not veins, of slate, are, in turn, confusedly strewed through the granite. This small bed dips north at a very small angle; but indeed so little of it remains on the granite, that its dip cannot be very correctly ascertained. There is another smaller patch of slate a few hundred yards to the westward of Sennen Cove, at the foot of Pedn-men-du point.

3. *Cape Cornwall.*

The next patch of the *slate formation* that we meet with, in proceeding along the coast, commences at Porth Just, on the southern side of Cape Cornwall, and extends to Pendeen Cove. In this range its mean width is little more than a quarter of a mile. At one point, on the northern side of the Cape, the granite reaches the cliff, to the exclusion of the slaty rock, for a considerable space. At another point, a little to the westward of Trewellard, the large granite boulders, shewing the near presence of their native rock, are thickly strewed over the brow of the cliff in their *growany* soil; but the cliff is still of the slate formation. The whole of this line of coast is rugged and precipitous, but less so than some of the granite cliffs to the south-westward. The structure is here more complicated, as it contains a greater number of rocks, and an increased variety of simple minerals; it is still, however, comparatively simple and satisfactory. The rocks on this part of the coast are the slaty felspar rock, hornblende-rock, and greenstone, which occur in beds of various magnitude, alternating with each other, and preserving great uniformity of dip and direction.

The following is the order of their occurrence: First, slaty felspar rock;—this includes the whole of Cape Cornwall: next, hornblende rock;—this includes the rock called Carnidjack Castle:

then slaty felspar; greenstone; slaty felspar; greenstone; slaty felspar; hornblende-rock: the picturesque rocks of Botallack mine form part of this bed. The same alternation of slate and hornblende-rock continues to the termination of the patch, making, in all, as near as I could ascertain, eight beds of the slaty felspar rock, and a like number of the hornblende or greenstone rock. The dip of all these beds is north, with an inclination varying from 20° to 40°.

The character of these beds is, I think, very distinct and obvious: the only rock to which I have doubts of having given the proper appellation, is that which composes the cliff of Carnidjack Castle. I have called it *hornblende rock*, but, I confess, rather from its relations to the other rocks, than from its individual characters. From its sonorous qualities it has been called by some "the ringing rock of Botallack." This rock decomposes on the great scale, in the form of basaltic fragments, which are strewed over the cliff in a very picturesque manner. In its more intimate disintegration, it assumes a rough granular surface, from the circumstance of the larger granular pieces of which it is composed, resisting for a longer time the operation of the decomposing causes.

The beds of hornblende on this part of the coast, especially those between Botallack and Trewellard, contain many small veins of actyno-

lite, which are extremely common in all the hornblende rocks of this part of the country. In the compact hornblende-rock near the Crown engine at Botallack, there is a large imbedded mass of garnet-rock. In the same place there is also found thallite, or epidote, and in the point of junction between a bed of this kind and a slaty bed, near Huel Cock, axinite is found in considerable quantities. In the whole tract of coast the different beds, although, as beds, very distinct, intermix at the line of opposition, so as, in many cases, to pass into each other.

In many points along this part of the coast, the beds of slaty felspar contain a great deal of common quartz in the form of thin layers, following the slaty fracture of the rock; or small contemporaneous veins crossing the slaty structure: this last is, however, much more rare. And I have uniformly remarked, as well in the beds on this part of the coast, as in every other part I have examined, that wherever this intermixture of quartz layers occurs, the rock loses its ordinary character of straight lamellar structure, and assumes a bent or twisted form. This is well seen in the rock which forms the upper part of Botallack cliff, and in the bed that extends from Pendeen sand-cove to the termination of the patch.

At its eastern and western extremities, this patch of the slate formation is traversed by a

great many veins of granite. Those at the former spot are described by Dr. Davy, in the first volume of our Transactions. About one hundred yards from the exposed point of junction of the two rocks, there is a vein upwards of four yards wide, whose direction is nearly east and west. It has many of the characters of those large veins of felspar porphyry, so common in the slate formation of this county, and to which the name of Elvan channels is usually given. I regret much that the accumulation of alluvial soil prevents us from being able to trace this channel to the main body of granite, as this might possibly enable us to solve the problem of the nature and origin of these curious masses.

In the cove a few hundred yards to the east of Cape Cornwall, the cliff is again cut across by a mass of granite eighteen feet wide. This is in the neighbourhood of the patch of shorl-rock already noticed in a former part of this paper.

At the eastern termination of this formation, the slaty rock is traversed by an infinite number of granite veins. Some of these are a foot and half wide, and can be traced for a considerable length. They run in all directions; but all those exposed to our view, have more or less of an east and west direction. At this point the slate is also much intermixed with small veins and layers of quartz.

4. *From Polmear to St. Ives.*

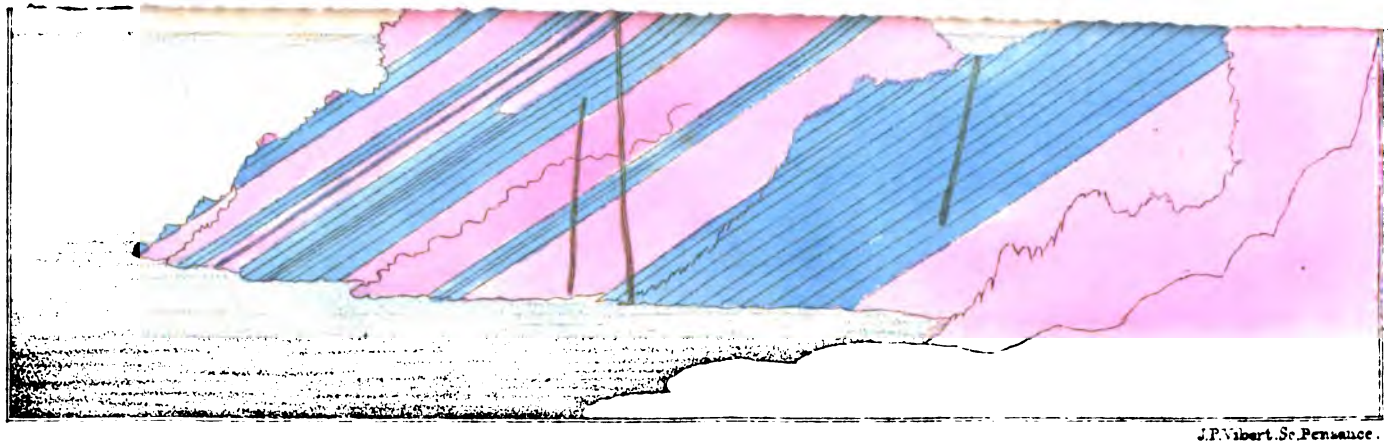
The only other body of slate formation that remains to be noticed, is the great mass which can be traced from the village of Polmear on the north coast, to the village of Mousehole in Mount's Bay, crossing the interior in the line from Hayle to Marazion. In describing this tract, I shall, for the sake of precision, divide it into three portions; the first including the coast from Polmear to St. Ives; the second, the shores of Mount's Bay, from Mousehole to Cuddan Point; and the third, the tract extending from the southern to the northern shore.

From Polmear to St. Ives, this formation, as may be seen by a reference to the map, is still a mere border, lining the shore. In no place does it extend into the country so much as a mile: in one point, a little to the eastward of Zennor church, it scarcely conceals the fundamental rock.

The whole of this line of coast consists of rocks precisely similar in individual character and external relations, to those already described. In some parts of the coast, particularly near the village of Boswednan, actynolite occurs in great quantity, in veins, both in the hornblende and slaty rock. The rocks on this part of the coast possess nearly the same direction, dip, and inclination, as those in St. Just: that is to say, they dip north, at an angle varying from 25° to 45°.

In thus summarily disposing of the geology of this part of the coast, I must be permitted to say a few words on the promontory of *Gurnard's head*, in the Parish of Zennor, which I would recommend to the attention of the young geologist, as affording an excellent illustration of the nature of stratification in general, and as the clearest example of the general characters of that particular assemblage of rocks which immediately repose on the granite in this part of Cornwall, to which I have given the name of the slate formation.

The *Gurnard's head* is, perhaps, one hundred yards wide, and five or six times that space in length. It runs out into the sea in a direction nearly north, and its sides, particularly the western, are nearly perpendicular: it therefore exhibits a grand natural section of the strata that compose it: these are the following,—first, hornblende-rock, forming the grassy brow of the shore; next, slaty felspar, of the thickness of one hundred yards; then regularly alternating beds of this rock and hornblende-rock, or greenstone, to the number of twenty or thirty, of all magnitudes, from a few inches to twenty feet in thickness;—the thickness of the slaty beds, however, exclusive of the one first mentioned, is not nearly so great as that of the beds of hornblende-rock or greenstone. At one point of this natural section, an instructive example of what



J.P. Vibert. Sc. Penzance.

THE GURNARDS HEAD.

Published by T. Vigurs, Penzance. 1822.

is called by geologists the *wedging out* of a bed, is observable. This feature is shewn in Plate VI. and I apprehend it must be a frequent one in every assemblage of contemporaneous bedded mineral masses. This sketch is a correct representation of the stratification of the whole promontory, being merely a fac-simile, only with finer outlines, of what the natural section displays. The direction of these strata is nearly east and west; their dip is, consequently, north; and the angle of inclination varying from 30° to 45°.

If the promontory of Gurnard's head be well calculated to show the nature and relations of the rocks composing the slate formation; different parts of the same coast exhibit most beautiful and instructive illustrations of the curious phenomena usually observable at the points of union of these rocks with the fundamental granite.

This is particularly the case at the cliffs under Polmear, and on the coast immediately to the westward of Zennor Church. In this last place the sea-cliff runs, for the space of perhaps half a mile, on the very line of junction; and this lays open to our inspection an endless variety of appearances, which, from their rarity in other countries, and their having become the grand arena of geological combat, have acquired a value and an interest which en-

title them to particular notice. As affording striking examples of the phenomena in question, St. Michael's Mount has, of late years, become as famous in the annals of geology, as it has always been in the pages of the antiquary and the tourist; but I may venture to say, that the very superior claims of the Zennor cliffs, in this particular point of view, had they been equally within the scope of the common traveller, would have, long ere now, completely dispossessed *the Mount* of the rank which it now holds among the weapons of polemical geology.

At the most western point of Polmear Cliff, where the two formations come in contact, the granite is traversed by a great many shorl-rock veins. At one particular spot, these, running vertically, divide the granite into vertical masses, similar to those observed on the south side of St. Michael's Mount. The display of granite veins traversing the slaty rock, is here particularly splendid. In several places, large insulated masses of the granite, many yards in diameter, are seen lying in, or protruding through, the slaty rock, and giving off veins,—some of considerable width,—in all directions: several of these are seen rising vertically to the summits of the precipitous cliffs, and some can be traced to the edge of the sea at low water. Two of them, one twenty inches wide, the other a foot, cross one another, and, at the point of inter-

section, exhibit the phenomenon called a shift, or heave. The shift in this particular instance is about four feet.

These, and other veins which appear in the lower sea-cliffs, are again visible, and in a more picturesque character, in the lofty and precipitous rocks that crest the grassy summit of this romantic shore.

In one part of the cliff, the granite veins are intersected by a vein of shorl-rock, which can not only be traced into the main body of granite, but is seen running through the granite itself to some considerable distance. In intersecting the granite veins, the shorl-rock does not cause any shift in them.

I may here observe that the inclination of the strata of the felspar rock, neither at this place, nor at any other point where the two rocks come in contact, seems to bear any natural or necessary relation to the inclination of the granitic *surface* on which they rest. At this place, for example, and all along the shore beyond Zennor Church, the stratification, or slaty fracture of the felspar rock, uniformly retains its inclination north, at an angle of about 30°, whether the surface of the granite on which it lies incline east, west, north, or south; whether it be horizontal, vertical, or form any intermediate angle with the horizon. This fact seems as irreconcilable with the Wernerian theory of

the formation of rocks, as the one just mentioned, of the intersection and shifting of a granite vein by another vein of the same individual mass, appears to me to be subversive of the Huttonian hypothesis; but in truth, facts irreconcilable with these, and all other theories that have yet been invented by man to explain the operations of the Deity in the formation of the earth, are too numerous to allow those just mentioned to excite much surprize.

The appearances in the Zennor cliffs are equally curious. Indeed the two rocks are so intermingled, as irresistibly to suggest, and confirm, the belief of a contemporaneous origin. The slate is traversed in all directions by innumerable veins of granite; while the granite contains inclosed in it innumerable patches of slate. In some of the perpendicular cliffs, the two rocks, at first sight, suggest the idea of beds alternating with each other; yet this is by no means the case; the patches of slate proving, on examination, to be merely superficial masses, filling up horizontal cavities in the granite. These appearances are instructive, as shewing how easily the true nature of the relations of rocks may be misunderstood, without due examination.

At St. Ives, the strata alter their inclination to the eastward, agreeing, in this respect, as well as in their other characters, with the rocks in Mount's Bay.

I have now to give a concise description of the remaining portion of the *Slate Formation*; namely, that which is continuous from the village of Mousehole, along the shore of Mount's Bay, to its termination near Cuddan Point, and which stretches across to the northern shore. The *Slate formation* on this part of the coast is of much greater extent than that which has been already noticed: it gradually increases in width from its western limit at Mousehole, till it reaches from shore to shore, and stretches in an east and west direction, from Castle Endinas to Tregoning Hill.

The whole of this Formation, like the insulated portions of it already described, reposes on the granite which constitutes the centre and main portion of the Land's-end district. It consists also of the same rocks, viz. compact felspar, slaty felspar, greenstone, hornblende-rock, and clay-slate, all of which preserve the same relations to each other, and to the subjacent rock, as those already described; that is to say, they all rest on the main body of granite; they all dip *from* it at an angle varying from 25° to 45°; and they continue to alternate with each other in an uninterrupted series of beds of various magnitude.

The general inclination of all these rocks is towards the east: in many places indeed the line of inclination veers considerably to the

north and south of this point; but still it is sufficiently correct for all geological purposes to consider them as dipping towards the east. But to enter a little more into detail. At the western extremity of this series of rocks, at the back of Mousehole Pier, the junction of the slaty felspar rock with the granite is well seen at low water. The two rocks, at their junction, are, as usual, much intermixed, the slate being traversed in all directions by veins of granite and quartz, which intersect each other in numerous instances, and in various ways; and the granite, in its turn, including imbedded portions of slate, and being filled with patches and veins of quartz.

As usual also, the slaty rock contains a much greater portion of mica, than it does at a distance from the granite, and thus approximates, in some degree, to the characters of gneiss and mica-slate, with which, however, it has no right to be classed,—this being only a very partial feature of a rock, whose general characters are very distinct and different from both of these rocks. Respecting the phenomena exhibited by these veins, I am the less desirous to detain the Society with any minute details, as they have been noticed by another member. The whole of St. Clement's Isle, or Mousehole Island, as it is often called, consists of a single bed of this rock. It is of a beautiful purple colour,

containing little mica, and, upon the whole, exhibits as fine a specimen of the rock to which I have given the name of slaty felspar rock, as any rock on this coast.* It dips a little to the north of east, at an angle of between 30° and 40°. It is a single bed, and shews more decidedly the characters of *stratification*, than any single bed of the same rock on this coast. The strata are in some places beautifully waved, and vary from a few inches to many feet in thickness.

In tracing the line of the shore from Mousehole to Newlyn Pier, I think there can be distinctly traced about nineteen different beds, resting one upon the other, in the following order:

1. Slaty felspar rock; the rock already noticed as resting immediately on the granite behind Mousehole Pier.

2. Hornblende-rock, putting on in some places much of the character of greenstone. This commences immediately to the eastward of Mousehole Harbour, and continues all the way along the shore to Penlee Point, which consists of it, and which is a fine example of a well characterized and beautiful hornblende-rock.

3. A patch of the slaty felspar rock resting on the last rock, on its sea-border, but not interrupting the continuity of the hornblende-

* From its colour it might well be denominated *Purple killas*.

rock on the *shore-side*, which, as has been already stated, extends from Mousehole to Penlee Point.

4. Immediately on the north side of Penlee Point there is a bed of the compact felspar rock, which gets gradually more and more of the slaty character as we advance northwards along the shore, and finally terminates in what we must consider as a distinct bed of slaty felspar.

Then follow a succession of beds of compact felspar, and slaty felspar rock, to the number of fifteen, which continue to Newlyn Pier.

I do not mean to say that there are in this tract, nineteen distinct and separate beds. In reality there are, perhaps, only twelve or thirteen; but as the line of direction of the shore is, in many places, the line of direction of the strata; it frequently happens that after leaving one bed, and coming on another, we soon leave this also, and owing to the irregularities of the coast, we come once more on the bed we had previously left.

The general inclination of all these beds is several degrees to the south of east, or exactly towards St. Michael's Mount, under an angle of from 25° to 30°. The comparative hardness and consequent indestructibility of the slaty and hornblende-rocks, is shewn in Penlee Point, which we have stated to consist of very fine hornblende-rock, and which is the only bold and precipitous cliff on this part of the coast. The

slaty rock is much traversed by quartz veins, some of considerable size, all along the coast, but more especially near Newlyn Pier. The largest of these, which is upwards of a foot in width, is midway between Newlyn and Mousehole; there is another very beautiful vein, (*a cross course*) which follows the direction of the shore, for some distance, and traverses, in the greater part of its *exposed* course, the unstratified rock which I have called compact felspar-rock. It is principally of quartz, of a fine crystalline texture, but contains in its centre, in many places, a considerable layer of Ironstone, of a very flinty character. The hornblende-rock of Penlee Point, and the other rocks adjoining, are likewise cut across by a very large vein, consisting principally of quartz and chlorite, and having very distinct *way-boards* or *capels* of quartz, nearly two feet thick. It runs, like the others already mentioned, exactly north and south, and dips to the west at an angle of 60°.

The rock which I have named compact felspar rock, which consists principally, I believe, of compact felspar with a little quartz, I have so named in deference to my excellent and learned friend Professor Jameson: it may, however, be considered as a variety of greenstone. The only difference between it and common greenstone, is its containing a more minute portion of hornblende, and being, consequently,

of a lighter colour than that rock generally is. Many specimens of this rock are deposited in the Museum.

Advancing from Newlyn to Penzance, the first exposed rock is a hornblende-rock, with an imperfect slaty structure, dipping east at an angle of 30°. The next exposed patch of rocks (called the Pandore Rock) consists of a series of beds of hornblende-rock, more or less of a slaty character, and of an intermediate rock between the slaty felspar rock and the hornblende-rock. The peculiar modification of rock last mentioned, is here found in great quantity and beauty. It appears to be of the nature of very compact felspar, approaching to hornstone, and containing a great admixture of hornblende in small bunches of radiating crystals. It is extremely hard; in some places has an imperfect slaty fracture, and occasionally is found to contain specks of copper pyrites. It is found in considerable quantity on these shores, and appears to pass gradually into the adjoining well characterised rock of felspar or hornblende. In this patch of rocks axinite is likewise very plentiful, and it is probable that this mineral, in a compact form, assists to give the peculiar characters to this singular rock.

The range of rocks from the Pandore Rock to Penzance Pier, are precisely similar to the others, only that here, the hornblende-rocks have

more decidedly the character of greenstone, and the slaty rock verges more towards clay-slate, and is indeed, in several of the beds, decided, and well characterised clay-slate.

They consist of an uninterrupted series of alternating beds of greenstone and slate, various in thickness; but all preserving the general direction of nearly N.N.E. and S.S.W. and a consequent inclination to the E.S.E., at an angle of from 30° to 45°. This series of alternations continues all along the shore, across the Battery Rocks, and as far seaward in the direction of the Gear Rock (which is greenstone) as the water will permit examination. The Battery Rock is greenstone, as is also the round rock opposite to it on the west. The rock that formerly filled this cove, being of a softer slate, has been washed away.

The greater part of this patch of rocks is traversed by a large vein of felspar porphyry, of the width of, perhaps, twenty yards, which runs nearly east and west. A part of this vein supports the Pier of Penzance, and is seen swelling out from beneath its southern base. It is covered for a short distance by the houses near the Pier, and afterwards by the sandy beach to the westward of the Pier; but it soon makes its appearance and runs along the shore for a considerable distance in the direction of the village of Newlyn. It is very conspicuous

at low water, and one of its projecting concretions has obtained the name of the Chimney Rock. This vein inclines rapidly towards the north, perhaps at an angle of 60° to 70°.

Like all the large veins of porphyry in this country, (better known by the name of elvan channels,) this vein intersects indiscriminately all the rocks it meets with; and bears considerable indications of contemporaneous origin with the adjoining rocks. The most remarkable of these is the gradual transition of the porphyry into the bounding rock; a fact which is very distinct in many parts of this vein. Another fact is the absence of any thing like dislocation of the strata;—each rock which it crosses being found on the opposite side of the interrupting mass, precisely in the same line of direction as before, and as it would have been had no vein been present. An account of the singular mine (the Wherry) formerly worked in this channel of porphyry is given in the first volume of our Transactions: also the manner in which the tin ore was found in it.

In tracing the shore from Penzance Pier to Marazion, all the rocks, as far as they can be examined, are very similar, in every respect, to those just described. In the patch which extends from the Pier to Chyandour, their dip, and direction, and succession, are less distinct than in the places already noticed. There are some

beds of greenstone under the Bath-house; and the rocks under Chyandour cliff furnish an example of a fine hornblende-rock. As well as can be ascertained, these strata dip nearly south-east, at an angle of from 35° to 45°.

The rock called the *Creziers,* consists of a bed of greenstone; as does also another large rock, bare at low water, farther to the eastward.* A low ledge, consisting of thick slaty rock, continues the whole way to the *Long Rock,* which is seen stretching out like a pier into the sea, and principally consists of another large vein of felspar porphyry, very similar, in all its individual and relative characters, to the Wherry Mine vein. Indeed so very similar are these veins, that I at first believed this to be a continuation of the other; but their direction is so different as to forbid our entertaining this supposition; the Wherry Mine vein running nearly east and west, while this runs nearly north-east and south-west. The mean width of this vein may be about 30 yards. It seems to dip towards the north-west, but this cannot be easily ascertained. It is a beautiful rock, and offers a fine example of that configuration of rocky masses, called by Geologists the *seamed structure;* being a congeries of *distinct concretions,* of irregular forms and various sizes. This

* These rocks contain a larger proportion than usual of a whitish felspar, and thus approach, in external character, to sienite.

Channel also exhibits a very complete admixture with the adjoining rock. It is more porphyritic in some parts than in others, but seems in general to be least so at the edges, and more like compact felspar. On its northern border the slate seems to rest *on* it in patches. This Channel of Elvan is intersected, nearly at right-angles, by several veins, which appear to consist principally of chlorite: some of these have been lately worked for copper.

Between the Long Rock and Marazion, the thick slaty rock approximates, occasionally, to the characters of clay-slate. Its inclination is not very distinct, but appears to be nearly south-east, or towards the Mount.

There is another large bed, exposed at low water, nearly opposite the Mount Pier, consisting principally of that anomalous rock, which seems intermediate between hornblende-rock and slaty felspar. Being unstratified, its dip and direction cannot be ascertained.

The large insulated rock on the western border of the causeway that leads to the Mount, called the Chapel Rock, is well-marked greenstone. It rests on a bed of clay-slate which runs nearly north and south, and dips to the west, at an angle of about 20°. This is the first bed which we have seen on the shores of Mount's Bay having this direction. In this it agrees with the slaty rock on the western base of St.

Michael's Mount. Immediately to the eastward of the causeway, the arrangement is more confused, and it is not so easy to ascertain the true inclination of the beds. Some of them appear as if they inclined to the eastward, and some to the westward; and this is particularly true of some of the slaty beds on either side of several of the beds of greenstone, which are found on the shore immediately beyond Marazion.

In several places, so striking is the appearance of the two slaty beds dipping *from* the intermediate mass of greenstone, that the latter might almost be taken, at first sight, for a vein traversing the bed of slate.

Before reaching the Greeb Rock, there is a large vein, about ten yards wide, which runs W.S.W.: whether this is a granite vein, or a channel of porphyry, is not easy to decide. It is of a much lighter colour than the elvan channels formerly mentioned, and indeed altogether of a different character. It has the appearance of an intermediate substance between granite and greenstone. Its marks of contemporaneous origin with the adjoining rocks, are much more characteristic than those noticed in the elvan channels. It is not *seamed*, and shows no appearance of being composed of distinct concretions. The Greeb Rock consists principally of greenstone. It contains much actynolite, and also axinite.

The same irregularity in the direction and inclination of the strata, continues all the way to Cuddan Point. In the vicinity of Perran Cove, the slaty strata dip east, or south-east; but a little further on, on both sides of Cuddan Point, they dip, generally speaking, W.N.W., at an angle of 20°. In Trevean Cove (between Perran Cove and Cuddan Point) there occurs another vein of nearly the same width, and general character, as the one last described. Its direction is nearly east and west. Cuddan Point consists of hornblende-rock. Beyond it, the slate puts on, more distinctly, the characters of the thick slaty felspar rock (the purple killas) described as on the shore near Mousehole.

I have hitherto confined my observations on the Slate Formation of Mount's Bay, to the cliffs and reefs that immediately bound the sea-shore, and my knowledge of this Formation has been principally derived from this source. I can, however, state with certainty, that throughout the whole tract of country delineated on the Map as the Slate Formation, wherever artificial excavations, or natural deficiency of alluvial covering, permit the examination of the rocky masses, these are found uniformly to accord, in their individual and relative characters, with those grand natural sections exhibited on the shores. Greenstone and hornblende rocks, and also the slaty felspar rock, varying

occasionally to clay-slate, are found in extensive beds on the hill between Mousehole and Newlyn; on the hill between Newlyn and Trereife; on Tolcarne; at Castle Horneck; at Rosehill; at Alverton; at Lower Poltair; above Chyandour; in the Carns between Gulval and Kenegie; in Huel Fortune near Marazion; &c.

In all these situations the slate retains the same general inclination as it exhibits on the neighbouring shores, viz. east, or a few degrees north or south of this point; and this is the general inclination in every part of the western side of Mount's Bay. We have seen, on the contrary, that on the eastern side of St. Michael's Mount, the inclination is very various, and often opposite to that just mentioned; and we accordingly find this rock, in the road leading from Marazion, dipping N.N.W. at an angle of 20°.

Several other elvan channels have been discovered at a distance from the shore, consisting of very fine porphyry, but differing little in character from those already described.

To complete this sketch, I shall now give, in a very few words, an account of this Formation, as it is found stretching from St. Ives, along the shore to Lelant, and across the country to Marazion.

The inclination of the strata all along the coast from Cape Cornwall to St. Ives, is, as I

have already observed, nearly north. At St. Ives this direction is suddenly altered, and on all the coast as far as Lelant, the inclination is south. The first patch of slate that exhibits this new inclination, is a bed to the westward of the Battery of St. Ives, just at the eastern extremity of the large wall raised as a defence against the sea. The rocks are hornblende-rock and slaty felspar rock (purple killas). The general dip here is about 30°. The promontory on which the Battery is built, is composed of these alternating beds of greenstone and slate; and their disposition is well seen in the precipitous cliff on which the Battery stands. Of this cliff the upper and lower beds are of greenstone; the intermediate, slate. The quarries that afford stones for the Breakwater, are in a bed of greenstone,—a rock which affords perhaps the best possible materials for such a work. The same alternation of slate and greenstone, continues until the rocks are finally hid in the sand-hills of Lelant. The same southerly inclination prevails also, in a greater or less degree, in the rocks that constitute the country from Lelant to Marazion, which are nearly of the same kind as those already described.

I have now completed the description of the physical structure of the Land's-end district, with the exception of what relates to its mineral

repositories, and with the exception also of one of its most remarkable localities—St. Michael's Mount. The former of these, viz. the metalliferous and other veins that abound in many parts of this district, I have not yet found time to examine. Of the geology of St. Michael's Mount, I have prepared a brief outline, which I shall shortly have the honor to present to the Society.

With regard to the *nomenclature* adopted in this paper, although I am anxious to avoid the appearance of singularity, and desirous to be understood by Geologists, I am the less solicitous on this point, as I have laid before the Society, specimens of every rock which I have described. These will remain in their Museum to explain and illustrate my observations, and to confute or confirm the propriety of the names I have affixed to them.

In thus bringing to a conclusion a Paper which pretends to no other merit than that of being a faithful detail of facts, I ought perhaps to apologise for the total absence of any of those ingenious speculations or theories which, to some, may seem the very essence of geological discussions. I must, however, observe that theoretical subjects did not at all enter into my plan; and I humbly conceive, that I better consult the interests of the Society by

adding one new observation to its stock of facts, or one new specimen to its cabinet, than if I wasted my time and theirs, in the construction and exposition of theories, which would probably prove useless, and might possibly be ridiculous.

XIII.—*An account of the Alluvial Depositions at Sandrycock.*

By the late PHILIP RASHLEIGH, Esq.

(Drawn up in 1792, and communicated by John Hawkins, Esq. September, 1819.)

Between the Parishes of St. Austle and St. Blazey, there is a vale which, after conveying the waters of an extensive growan district to within one mile of the nearest part of the sea coast, and in the usual direction of the rivers on this side of the county, takes a turn at right angles to the eastward, and discharges its waters into the estuary called Par.

The length of this lower part of the vale is about one mile and half, and its breadth varies from half a mile, to one quarter, or less. Its surface is little elevated above the sea level at high water mark; and so even, as, when contrasted with the outline of the country around, to leave no doubt of its alluvial origin. The whole area was formerly good meadow and pas-

ture ground; but within these few years it has been worked for tin, and has been very productive of that mineral. There are here two considerable Stream-works called Poth and Sandrycock, by means of which all the alluvial beds have been sunk through, and exposed to view, as well as the killas rock on which they rest. It will be seen that from 40 to 44 feet of these have been accumulated here since the lodgement of the tin-ore.

Sandrycock work is situated nearly in the middle of the vale. I measured the different beds at the lower end of this excavation, by which it appears that the basin has been filled by drifts from the sea below, as well as from the country above.

	Feet.	In.
1. Vegetable mould about - - - - - - -	0	3
2. Gravel and micaceous sand, mixed with fine loam, in alternate beds of various depths, making together - - - -	8	3
3. Light coloured clay with a little mica, and a few roots of vegetables nearly decayed	5	3
4. Black peat - - - - - - - - - - - -	4	1
5. Light coloured clay - - - - - - - -	1	4
6. Stiff clay of a light brown colour, with some decayed roots of vegetables. The clay was spotted with light blue, like the native Prussian blue, both where the remains of vegetables occurred, and where they did not. - - - - - - -	3	10
7. Sea-sand and clay mixed - - - - - - -	3	0
8. Very fine sea-sand, together with mica and small fragments of shells and killas	4	0

	Feet.	In.
9. Coarser sand without shells - - - - -	6 -	0
10. A solid black fen, with a few remains of vegetables, in which are round globules of the size of middling shot, but not harder than the fen. This substance is not made use of as fuel - -	2 -	10
11. Tin-ground and loose stones of all sorts. This bed varies in thickness, from 1 to	6 -	0
12. Killas, on which the tin-ground rests, and in some places yellow clay.		

These different beds vary a little in the same stope; but not considerably. I attribute the formation of the alternate beds in No. 2, to the materials of which they are composed having been transported thither by land-floods of more or less violence. When I made these observations there were no pieces of timber found in that part of the work; but large branches of hazel, alder, and willow, frequently occur there. These are very black, and give a very disagreeable smell when inflamed. They contain too some vitriolic acid. The peat is exceedingly offensive when on fire.

The stream-work called Poth, which is situated very near the sea, resembles the work above it, in most particulars. A variety of animal substances are found here, nearly at the bottom of the sea-sand, and upon the sea-mud; such as the horns of Deer, and of the wild Ox. A pair of the latter measured fifteen inches round at the base, and two feet two inches and half in

the outward bend, from the base to the tip of the horn.

The whole Vale has a very little descent, so that the salt water would flow into Poth, were it not prevented by a flood-hatch; the beach, however, by the continual accumulation of mud and sand, is so much raised as to prevent the sea at high water from going up the moor, except by the adit.

XIV.—*Observations on the Alluvial Strata at Poth, Sandrycock, and Pentuan.*

By JOHN HAWKINS, Esq. F.R.S. &c.

HONORARY MEMBER OF THE SOCIETY.

(Read September, 1819.)

To the late Mr. Rashleigh of Menabilly, who communicated to me, in 1792, the preceding memoir, the merit I believe is due, of having first noticed the very interesting alluvial strata of the stream-works near St. Austle. His account of those at Poth is to be found at the end of his splendid publication entitled Specimens of British Minerals, &c. and Mr. Smith has presented us, at a subsequent period, with a very full account of those at Pentuan.

Little perhaps can now be added to the facts which have been so clearly stated by those gentlemen; for the works where they were observed and collected, have been long since abandoned. But they are sufficiently important to deserve the more general attention of men of

science, and they must suggest to every common observer some idea of those changes, which have taken place at a remote period, in the form of the surface of the earth.

In the following reflections on this subject, which I now submit with some hesitation to my colleagues, I have been led to the contemplation of results which may not be generally admitted, and which are certainly not capable of perfect demonstration; but if they should awaken a spirit of enquiry and discussion, the views of this Society would be promoted; and at a future period, perhaps, some new facts may be brought to light, which will render the problem here considered less difficult of solution.

Confining myself to the facts already stated, in regard to the strata of Poth and Sandrycock, the following appear to me to be the most important, in the formation of any hypothesis which can be applied to their explanation.

1. The direction of this part of the vale towards the estuary called Par, prevents it from having any direct communication with the open sea.

2. The level of its basin is considerably below that of low water mark.

3. The little declination of its basin, in this part of its course towards the sea, may be inferred from the section of the two stream-works.

4. All the tin-stone has been lodged at the bottom of this basin.

5. This bed of tin-stone is covered with vegetable, mixed with some animal *exuviæ*.

6. Above this, is a deposition of sea-sand to the height of ten feet, terminating in three feet of mud and sea-sand.

7. Then follow successive depositions of mud, which are evidently produced by the junction of the land-floods with the sea-water. This part of the stratification I would call precipitated alluvial; the rest, which is above this, as well as the tin-stone at the bottom, rolled alluvial.

The whole therefore may be arranged under three or four distinct periods or revolutions, or more correctly, under two great, and one or two subordinate periods.

The most important of these, appears to be that which deposited the sea-sand, for it indicates *a rise of the sea level.* And I conceive that the depositions above the sea-sand, have gradually usurped the place of the sea, and repelled it. This, in a few words, is the hypothesis by which I shall attempt to explain the phenomena above described: my colleagues, perhaps, may think it a very bold one, and will consequently suspend their assent, until some very strong inductive evidence is produced in support of it.

I presume that the tin-stone has been lodged at the bottom of this deep basin, *previous* to the deposition of the sea-sand, because if the sea-level was as high then as it now is, the sea must have quickly deposited here a thick bed of sand, the compactness of which would have prevented the tin-stone and the rubble which were subsequently brought down from a higher level, and here discharged into the sea, from sinking lower. Nor could their transportation hither have been effected by any other cause, than that of a land-flood; the propelling force of which may be conceived from the distance to which these portions of disintegrated rocks and lodes have been removed, and from their diffusion over a surface so level and extended. For the same reason, and, *a fortiori*, the vegetable *exuviæ* immediately above the tin-stone, must have been deposited here before the sea had risen to its present level.

But one of the most important inferences which may be deduced from these facts, is, that this great and violent disintegration of the primitive strata, and the removal of their fragments, are referable to one and the same crisis or catastrophe; for we see that all the heavier substances have been lodged in one situation: whereas, had this disintegration and removal taken place at different periods, or successively, the section of the alluvial strata here would present several alternate deposits of tin-stone.

The conclusion which I have drawn admits of some allowance for the duration of the period here alluded to, and for some changes or abatement of the propelling force, which will account for all that disorder in the mixture of the tin-grains and the gravel, which Mr. Rashleigh notices.

Of the antiquity of this great catastrophe there can be no doubt, when we consider the evidence of all the facts above stated; although the animal and vegetable remains which have been deposited immediately over the tin-stone, and in all probability by the same flood, shew that this period, in comparison with that which includes the formation of the solid strata of the earth, is recent.

Nothing indicative of the rise of the sea-level, is to be seen at Pentuan, the reason of which is, that the basin there, according to the report of Mr. Smith, is nearly on a level with low-water mark. The alluvial beds lie there immediately above the vegetable matter, and there is no sea-sand, although there are shells. The whole of these must therefore have been formed by a precipitation of the contents of the land-floods in the salt-water.

XV.—*On the Mineral Productions, and the Geology of the Parish of St. Just.*

By JOSEPH CARNE, Esq. F.R.S., &c.

MEMBER OF THE SOCIETY.

(Read October, 1821.*)

In all the compass of Great Britain, there is no district which presents greater attractions to a scientific observer, than the County of Cornwall; and of all the spots in Cornwall, most interesting to the Mineralogist and the Geologist, there is probably not one which, in so small a compass, has produced so many species and varieties of metallic and earthy minerals, or which presents to view so many geological peculiarities, as have been discovered in a part of the Parish of St. Just, near the Land's-end.

This Parish has been remarkable, from time immemorial, for its treasures of tin; but it is only of late years that it has been discovered to

* Some minerals which have been discovered since this paper was read, are included in the list, although they could not be noticed at that period.

be as rich to the mineralogist, as to the miner and the merchant. The establishment of a Society for the promotion of mineralogical and geological science, has awakened considerable attention to the mines and the coast of the western part of Cornwall, and to none more than those of St. Just: several species of minerals have, in consequence, been discovered, in situations where their existence was never before suspected; and many circumstances, interesting to the Geologist, have been brought to light.

That part of St. Just which is intended to be the immediate subject of this paper, extends in length from about a mile and half south of the village in which the Church stands, to two miles north of it; and in breadth, not more in any case than a mile and half from the sea: the whole space therefore comprises three miles and half in length, and a mile and half in breadth; but with respect to at least three fourths of the minerals which will be mentioned, the space may be reduced to the length of a mile and half, and the breadth of a mile.

An enumeration and specification of the minerals which have been from time to time discovered in this small district; and most of which are still to be found there; together with a description of the peculiar geological facts which have been hitherto observed in this Parish, may answer several useful purposes.

We will begin with the metals, and the different classes of earthy minerals shall follow.

METALLIC MINERALS.

1. TIN.

The *common tin-stone,* or *oxide of tin,* is more generally diffused in the veins which intersect this part of St. Just, than in those of any other parish in Cornwall, except St. Agnes; and although, from the insignificant appearance of many of the tin-mines, when placed in comparison with the larger mines of other parts of Cornwall, the ideas of a cursory observer, with respect to the quantity of tin produced, might be very limited; yet in the three months ending with last July, the ores of St. Just yielded more than five hundred blocks or eighty tons of tin: nearly one eighth of the whole produce of Cornwall.

The localities of this variety of tin are so numerous, that it is wholly unnecessary to mention them. Where it is crystallized, the crystal is usually an irregular octohedron. In Huel Owls, some specimens of the four sided columnar crystal, with the pyramid, have been discovered; and in a vein in the rocks below this mine, some long four-sided pyramids, without the prism, have been met with.

That rare mineral the *tin pyrites,* or *sulphuret of tin,* called also *bell-metal ore,* has been re-

cently discovered at Botallack, by Dr. Boase; but in so small a quantity as to be little more than sufficient to ascertain its constituent parts. As he met with it in one of the heaps of ore, it cannot yet be stated in what part of the mine it was found.

Wood-like oxide of tin, commonly called *wood-tin,* has been found in small fragments in Pillianeath and Pemeder stream-works, about a mile and half south of the Church.

Resinous oxide of tin, and *spathose tin ore,* have been found in the same places, in small rounded masses.

As these works have not been wrought for perhaps upwards of fifty years, I am not aware that either of the three species last mentioned is now found in St. Just.

Granular tin-stone, which is so common in other stream-works, has also been met with in these streams.

In the valley in which these stream-works were wrought, was found, some years ago, one of those pieces of pure tin, known by the name of *Jew's house tin* or *Jew's bowl,* weighing about five pounds. I could not learn the circumstances in which it was found, but the outside of it appeared to be in a state of rapid decomposition, and passing into the oxide of tin.*

* Lumps of this kind have been found near stream-works, in several parts of Cornwall, sometimes on the surface, and at others, at a small depth under it. The largest I have heard of weighed thirty-

With respect to the matrices or vein-stones of tin, it has been found in milk-white quartz, and in rock crystal, in Huel Diamond: in decomposed granite (which occurs in bunches in the lodes) in Huel Diamond, Huel Bellon, Higher Botallack, Little Bounds, &c.: in granite of which the principal part is mica, in Huel Bill: in a mixed stone which appears to be composed principally of chlorite, with quartz and shorl, in Little Bounds: in brown iron-stone, in chlorite, and also in compact and very hard hornblende-rock, in Botallack.*

2. COPPER.

Although this metal is but sparingly distributed in St. Just; many varieties, and some very rare ones, have been discovered there.

Of *native copper*, a rare variety, known by the name of thunderbolt copper, because of its

seven pounds, and when last found, it formed part of a hedge in the Parish of Gwinear, having been probably carried there from its original locality. The places where they appear to have been smelted are called to this day *Jew's Houses*. The supposed origin of these terms may be known by consulting either Pryce or Borlase. It is singular that the mode in which these lumps are supposed to have been smelted, should be very similar to that which appears to have been originally adopted by the American Indians to smelt their silver ores. Humboldt tells us that, according to the traditions of the Indians, the ancient inhabitants of Quito smelted silver minerals by stratifying them with charcoal, and blowing the fire with long bambou reeds.

* The provincial, or rather parochial name of decomposed granite, when found in the veins, is *keethan:* of the mixed stone, *ramp*; and of the hornblende-rock, *blue elvan*.

forked appearance, was found in Huel Cock. The mine of Tolvaen near Huel Cock, produced another variety, consisting of very fine wires apparently twisted together like fillagree work. Arborescent native copper is not uncommon in Botallack, and some good specimens of it have lately been found there.

Red oxide of copper, in capillary crystals, and also in minute octohedrons, and cubes, which are sometimes elongated, has been met with in a vein near Botallack.

Ferruginous oxide of copper generally called *tyle copper*, has been lately discovered, massive, in Huel Edward.

Black copper ore has also been found in the same mine.

Yellow sulphuret of copper, or copper pyrites, occurs in mass, in so many parts of St. Just, although in small quantities, that its localities need not be particularly described. A specimen of obtryoidal sulphuret from Botallack is in our cabinet.

Purple copper ore, of the kind called by the Germans *Buntkupfererz* is frequently met with in the grey sulphuret of Botallack.

Vitreous copper ore, or grey sulphuret of copper, is common in Botallack, Levant, and Huel Spearn. In the former mine, beautiful specimens have at times been discovered, crystallized in octohedrons, and hexahedral plates

crossing at right angles. In Levant, the crystals are six-sided prisms with terminal edges replaced, four-sided prisms terminated by four-sided pyramids, and three-sided prisms terminated by three-sided pyramids. In Huel Spearn, a few specimens were found several years ago, crystallized in cubes.

Green carbonate of copper, or compact *malachite*, was found some time ago in Huel Cock, and has lately been found in Huel Edward, botryoidal, and incrusting quartz.

Blue carbonate of copper, has lately occurred in Huel Cock, in small round spots.

Chrysocolla, or *siliciferous carbonate of copper*, is quite new in St. Just. A few specimens of it have been met with very lately in Huel Edward, of various shades of green, yellow, brown, and black; accompanying arragonite. The black appears like pitch copper.

The vein-stones of copper are fluor spar, brown iron-stone, chlorite, and hornblende-rock (blue elvan) in Botallack: granite in Huel Spearn, and in a part of Botallack; and quartz in Huel Owls and Huel Castle.

3. IRON.

The ores of this metal are very plentifully distributed in St. Just.

Specular iron ore has been found in Carnyorth Moor, beautifully crystallized in hexahedral

plates, octohedrons, and various modifications of the rhomboid. Some of the specimens from this mine may vie (except in the size of the crystal) with those from Elba. Similar crystals, but not so fine, have been discovered in Parknoweth and Huel Owls. This mineral has also been found in rhomboids in Huel Bellon; in hexahedral prisms, in Huel Owls; in needle crystals stellated, in Boscagel Downs; and in mass, called iron-glance, in Botallack.

Red hæmatite was formerly found plentifully in Huel Bellon, and is frequently met with in Botallack.

Scaly red iron ore occurs at Little Bounds, sometimes investing quartz, and occasionally in small masses consisting of red cohering scales, which are unctuous to the touch.

Red chalk also occurs in the same mine.

Brown Hæmatite is plentifully found in Botallack, Parknoweth, Little Bounds, and Huel Bellon, and also in the old heaps of Huel Cock. This mineral is frequently mistaken for black hæmatite; but the scratch of a knife shews the brown streak. The latter is very rare, if found at all in St. Just.

Wood-like oxide of iron, commonly called *wood-iron*, has been found in great plenty in Boscagel Downs, and Botallack.

Brown iron-stone, or *compact brown iron ore*, composes a large part of many of the tin lodes, especially in Botallack.

Black iron ore has lately occurred in very small quantities, connected with uranite, at Huel Edward.*

Jaspery iron ore is sometimes found in one of the lodes of Botallack.

Spathose iron ore, or *carbonate of iron*, has of late been very abundant in the lodes of Botallack, crystallized in circular tables, hexahedral plates, and rhomboids. The colour varies from greyish white to deep brown. A great number of specimens have lately been found in the Crown lode of this mine, consisting of large supposititious crystals of this mineral, on brown iron ore, brown hæmatite, and stalactitic quartz. The crystals are flattened rhomboids, all of which are hollow, and some of them exceed half an inch in size. Several of these are beautiful cabinet specimens. The colour of the crystals is, in general, a light brown; but I have seen some nearly white: the latter probably contain a large portion of lime. This mineral has also been found in Huel Owls and Huel Bellon, in crystals of a singular form, which may perhaps be best described by a

* As this ore has not often been described, I subjoin the following particulars respecting it, from the information of Robert W. Fox, Esq. who has attentively examined it.

"It approaches more nearly to the ochery variety than to any other. It is friable, of a dark blueish black colour, and a black streak: its form is botryoidal: it does not soil the fingers: it becomes magnetic before the blow-pipe, and imparts a violet colour to glass of borax: it is not affected by nitric, but is entirely soluble in muriatic acid. It appears to contain oxide of manganese."

six sided prism, with acute angled triangular terminations: the sides are curved inwards at the middle, and the edges and angles are rounded. It is possible, however, that this crystal may be "an acute rhomboid, having its termination replaced by a triangular plane."

Arseniate of iron, until lately, was not known in St. Just; but it has recently occurred in the crown lode at Botallack, of a brown colour, crystallized in cubes.

Iron pyrites, or *mundic*, although not plentiful in St. Just, is frequently found massive, with sulphuret of copper, in the lodes of Botallack, Huel Owls, Huel Castle, &c.

Magnetic iron pyrites is not uncommon in the Botallack lodes, and abounds in the rocks near the crown engine, in which it occurs massive, in beds. Its colour is blueish grey. The workmen call it spelter, probably considering it as blende.

All the ores of iron which have been described (except the magnetic pyrites in the crown rock) occur either in the tin and copper lodes, or in certain cross lodes, which may well be called iron lodes; (of which there are some of considerable size, which traverse the greatest part of St. Just from north to south,) particularly when the tin and copper lodes and the iron lodes fall in with each other. These cross lodes will be mentioned hereafter.

In the Little Bounds mine, in the forty fathoms level, on the lode called the Little Bounds lode, there has been for several years a continual formation of stalactites and stalagmites, consisting principally of oxide of iron. These have been mentioned by Mr. Majendie, in one of the notices in our first volume. They are of such a delicate texture that, unless handled with great care, they fall to pieces.

4. LEAD.

Sulphuret of lead, massive, in quartz, and in fluor spar, has been sparingly found in Botallack, and accompanying pearlspar, in a vein in the slate cliffs below Huel Castle. These are almost the only instances in which lead has appeared in St. Just.

5. GOLD.

Small particles of this precious metal have been found in the stream-works which have produced the wood-tin, as beforementioned, but which are now abandoned.

6. SILVER.

I have never seen silver from St. Just, nor heard of it from any of the miners there. I mention it on the authority of Dr. Borlase, who says, "In a copper mine called Huel Cock, in "the Parish of St. Just, native silver has been "found among the copper ore:" and in another

place he says, "Silver found in Cornwall by "itself unmixed I have never seen but once, "and that was found native, about the bigness "of a walnut (of which I have a part), in Huel "Cock, a copper work in the Parish of St. "Just."* This must have occurred nearly seventy years ago. I question whether any silver has been found there since.

7. Bismuth.

Native bismuth has been found in two of the tin and copper lodes of Botallack, in coarse red jasper. The best specimens were discovered several years ago, and are now difficult to be obtained†; but inferior specimens are frequently met with. The miners ascertain the presence of this metal by exposing the stones supposed to contain it to the heat of a strong house fire, when it quickly oozes out in small globules.

Sulphuret of bismuth, in minute, bright grey crystals, tarnished yellow externally, imbedded in, and intimately mixed with vitreous copper ore, has occurred in the copper lode of Huel Cock.

Cupriferous sulphuret of bismuth has lately been found massive, in the crown lode of Botallack: its colour is dark grey, between that

* Natural History, pp. 208, 209.

† Just as this paper was going to the press, I was informed of a new discovery of beautiful specimens of this mineral, of which some were brought me, equal to any that I have seen.

of native bismuth and that of grey sulphuret of copper.

8. COBALT.

Arseniate of cobalt, of an earthy red and occasionally a bright red colour, is frequently found imbedded in the crown rock, close to the crown engine in Botallack.* It has also occurred, with axinite, in the slate rocks of Roscommon cliff. I have never observed it crystallized.

Arsenical cobalt, of a bright white colour, generally accompanies the arseniate of cobalt, in the crown rock.

Black earthy cobalt, the oxide of that metal, has been met with investing massive axinite, and also in a pulverulent state, in Roscommon cliff.

9. ARSENIC.

This metal has hitherto been discovered only as a large constituent part of very white pyrites, in the tin and copper lodes of Botallack, and in the copper lode of Huel Castle, in which it is very plentiful.

10. ZINC.

This metal is not so plentiful in St. Just, as one would expect to find it in such a metallife-

* This rock is well worthy of the attention of Geologists, on account of the numerous minerals which it contains, and of their curious mixture.

rous district. The only variety which has yet been found there is the *sulphuret of zinc*, or *blende*, and that sparingly, and in mass, in the crown lode at Botallack: it has also occurred accompanying pearlspar in a lode in the slate rocks under Huel Castle. Some specimens from the latter place have contained a small quantity of the *sulphate of zinc*, arising probably from the decomposition of the sulphuret.

11. Antimony.

Of the existence of this metal in St. Just, the only evidence is the discovery of a few small pieces of the sulphuret, very lately, in the old heaps near Huel Cock, one of which was brought to me. It is regularly striated; but its character is rather different from that of the antimony of Endellion. These might possibly have been found either in the copper lode of Huel Cock, or in the cross lode which runs into the sea at Roscommon cliff.

12. Uranium.

Oxide of uranium, or *uranite*, has been very lately found in the copper lode of Huel Edward, crystallized in quadrangular tables, of which the angles are sometimes truncated; and also in four-sided prisms, with the lateral, and occasionally the terminal edges replaced. In one or two instances the obtuse octohedron has occurred, formed by an aggregation of thin laminæ. It has also been found in needle-form and spear-

form crystals, forming druses, and botryoidal and globular concretions. Its colour has varied from white, passing into whitish green, through various shades of green to bottle green, brownish green, and rusty brown, and in some cases the extremities of the crystals have appeared nearly black. The needle-form crystals have been met with of a white, and yellowish white, passing into a deep bright yellow, and the same crystal has more than once been found partly green and partly yellow.

Uran-ochre, of a yellow colour, has occurred in the same mine, in a pulverulent form.

EARTHY MINERALS.

1. SILICEOUS.

There are two minerals which ought to be mentioned in this class before the others, because most of the others are found in one or other of them.

Argillaceous shistus, or clay-slate (which although called argillaceous, contains more silex than argill). This rock does not often appear separately, in St. Just; there are however some parts in which it is found, particularly near the southern termination of Pendeen Cove, where it is very decided. On most other parts of the coast of St. Just, it is mixed with rocks of a different kind, which will be described in the next article.

Hornblende. The stratified rocks which overlie the granite of St. Just, appear to have a great deal of hornblende in their composition, and to deserve the name of hornblende rocks. Their texture is generally slaty, but sometimes it is very compact. They contain, in different parts, (besides hornblende) quartz, felspar, chlorite, and other minerals. I have given the name of slate to the whole, although they have been of late frequently called greenstone. The slaty rocks in general have certainly a better title to the name of greenstone-slate, or hornblende-slate, than to that of clay-slate. Greenstone however is a word whose application is becoming almost as general as that of greywacke was some years ago.

I have never observed any greywacke in St. Just: on the contrary, the shistose rocks, from their appearance, situation, and the minerals which they contain, have the strongest claim to be considered as rocks of the primitive series.

These slaty rocks are the *killas* of the St. Just miners, as clay-slate is the *killas* of the central mining district of Cornwall.*

* The term killas is not confined to those rocks. Shew a miner primitive clay-slate, or transition slate, or micaceous slate, or greywacke slate, or hornblende-slate (if it be not very hard), and he will call the whole *killas*. Much therefore as we may wish to exchange a harsh German word for a word of English sound, we cannot unite with some eminent Mineralogists, in applying the term killas to greywacke-slate alone, whilst it, in reality, belongs to so many other substances. So far indeed is it from being confined to greywacke-slate, that perhaps nine tenths of the killas of Cornwall consists entirely of clay-slate.

Hornblende, mixed with apatite, is frequently found in the slate cliffs below Huel Cock.

I now proceed to mention the minerals which are found in these and other rocks.

1. *Quartz* occurs, of course, in all the granite of St. Just; and is otherwise very general, as it frequently forms the vein-stone of the tin and copper lodes. There are however some varieties of it which ought to be particularly noticed.

Rock-crystals, generally called Cornish diamonds, were plentifully found some years ago in the tin lode of a mine, which from that circumstance, was christened Huel Diamond. Of these, some exhibit the outside of the crystal quite opaque, but when cut, the inside is quite transparent: these are still common. I have seen one crystal from this mine which presents the singular phenomenon of a hexahedral prism surmounted by a pyramid of only five sides.

Black quartz, in brilliant minute crystals, and also in large ones, sometimes perfectly terminated at both ends, has been found in the tin-lode of Little Bounds mine.

Brown quartz, in long transparent crystals, has occurred at Trewellard.

Quartz has also been found in Little Bounds mine, of a bright brownish red and yellow colour; but these colours do not, in general, penetrate far into the substance of the crystal.

Amethystine quartz, finely coloured, has been met with in the same mine, and it is now tolerably plentiful in a lode near Bosavern mills.

Praze, or green quartz, has occurred in Huel Bellon.

Botryoidal quartz. Of this I have seen a few specimens from St. Just; but I have not been able to ascertain their locality.

Radiated quartz has been found near the old heaps of Huel Game. This might with great propriety be called hæmatitic quartz.

Stalactitic quartz. Specimens of this variety, as fine perhaps as have ever been met with, have been lately found in one of the lodes of Botallack.

Eisenkiesel, or ferruginous quartz, has occurred at Huel Owls, massive, and of a bright yellow colour.

Quartz is likewise found assuming the form of other crystalline substances, such as pearl-spar at Huel Cock; felspar at Boscagel downs; various modifications of the carbonate of lime and iron, in the crown lode of Botallack; and coating brown hæmatite, both botryoidal and stalactitical, in Little Bounds, and Huel Cock. It also occurs cellular. Frequently the crystals enclose others of the same substance, both colourless and amethystine, as at Huel Diamond. Crystals are met with enclosing shorl, at Roscommon cliff; chlorite, and oxide of iron, at

Botallack; oxide of tin, and copper and iron pyrites, at Huel Diamond.

2. *Opal.* This mineral has been found in the tin lodes of Huel Stennack and Huel London. Its colour varies from white, through the different stages of grey, yellowish brown, and black; and it is sometimes found of a red and bright yellow colour. It is translucent, opaque, and sometimes decomposing. The most translucent varieties reflect the red ray in a good light. It seems to pass into red and brown jasper, the transition being often imperceptible. It occurs in thin alternate layers, of different colours, with brown and red jasper, producing a beautiful striped appearance; and also in very minute veins. Globular opal has lately been found near Trewellard. Opal has also occurred, although much inferior, in the Bunny, and in the tin lode of Huel Spearn.

3. *Chalcedony.* This has been found in its usual botryoidal form in one of Botallack lodes; and, coating quartz, in the tin lode of Boscagel Downs; and also accompanying shorl, in the Bunny.

4. *Jasper.* This mineral is not at all uncommon in St. Just. Common red jasper has been found in the tin and copper lodes of Botallack, and Huel Spearn, and in the tin lodes of Huel Stennack and Little Bounds; and black jasper,

near Botallack; all massive. In the latter mine it is sometimes met with in a botryoidal form.

5. *Hornstone*, of a deep blood red, and also of a brownish white colour, and of a stalactitical form, has occurred in one of the lodes of Botallack.

6. *Garnet*. This semi-precious stone is not at all new in St. Just. There is a vein of garnet-rock, in the crown rock of Botallack, which abounds in very coarse garnets, irregularly crystallized. About six months ago, a mass of beautiful garnets, of a deep red colour, was found imbedded in the rock,* not far from low water mark, at the foot of Chycornish Carn, about a quarter of a mile south of Botallack. Some of the crystals were larger than hazel-nuts, and most of them were twenty-four sided. Some specimens of a very superior order were procured, each having from one to two hundred crystals on its face. Garnets, in rhomboidal dodecahedrons, of a yellow, yellowish brown, and brownish green colour, have been found in the slate rock at Roscommon cliff; and, as I have been informed, imbedded in carbonate of lime, near Lewellin.

Some small garnets, of a bright yellow and orange colour, and quite transparent, found in the same cliff, have been called colophonite;

* The rock here appears to contain chlorite, as well as hornblende and quartz.

but I apprehend this mineral is never found crystallized: its name therefore cannot belong to those small, but regular crystals.

7. *Prehnite.* This mineral, until very lately, has been quite a stranger to Cornwall, and has been little known in any part of South Britain. A few months ago, a great number of specimens were discovered in the slate rocks between Botallack and Huel Cock, in which it seems to form a small vein, which, in one part, is divided into two branches: some asbestus and zeolite have also been found in it. When crystallized, the prehnite generally appeared in the form of a circular mass of compressed rhomboidal crystals. I have, however, seen two specimens which evidently approach the octohedron.

8. *Zeolite.* On the discovery of prehnite, an expectation was naturally formed that zeolite, a mineral frequently connected with it, and equally a stranger to Cornwall, would soon make its appearance. This has been realized by the discovery of at least two varieties of it; both in the prehnite vein; viz. the stilbite, or foliated zeolite, crystallized in flat four-sided prisms, with wedge-like summits; and the radiated mesotype, which sometimes contains nodules of prehnite. Some specimens have also been found in rather an earthy state, which may possibly be the mealy zeolite of Jameson.

9. *Axinite.* Inferior specimens of this mineral, both massive, and crystallized, are very common in Trewellard and Huel Cock cliffs, and in the crown rock at Botallack; but a vein of it has lately been discovered in the slaty hornblende rocks of Roscommon cliff, which has produced specimens equalling in beauty the celebrated ones from Dauphiny. The crystals are of a light grey and violet colour, from translucent to transparent, and their form is generally an oblique rhomboidal table: a few crystals have been met with having more of the prismatic form, but of which it was hardly possible to determine the number of sides.

10. *Tourmaline.* Black tourmaline may be found, in great abundance, in the old heaps, on the side of the precipitous hill which is skirted by the road leading to Botallack. It was discovered in a part of that mine called the Bunny, in floors, between the granite and the slate. It is very irregularly crystallized, but generally prismatic; perfect summits, however, are rarely to be met with.

11. *Shorl* is very plentiful in St. Just, and may generally be found between the granite and the slate, wherever their junction occurs, and also in many of the tin lodes: it is usually striated, but I have found it completely stellated on the old heaps of Huel Cock. Some specimens have been found at Roscommon cliff, crystallized

in minute prisms. The prevailing colour of the St. Just shorl is bottle green, translucent on the edges; but the small prismatic crystals are often white and transparent.

12. *Actynolite.* This occurs in small veins in the slate and hornblende rocks near Cape Cornwall, and also in Botallack cliffs. Its general appearance is that of a mass of compressed crystals, from bottle green to deep brown. A large vein of asbestiform actynolite occurs in the slate cliffs below Huel Owls, almost as low as high water mark. Its contents however are very much decomposed.

13. *Epidote, or Thallite,* is found in a vein in the crown rock at Botallack, but in a part so difficult of access, that one would suppose that no specimens could be obtained from it but at the risque of life; yet the miners descend the precipice without fear. It is generally crystallized in four and six sided prisms: some crystals have been found of six sided prisms, accuminated on the extremities by three planes, the angles formed by the meeting of which, are truncated. Epidote is visible in many other parts of the same cliff, in veins, and has also been found in the tin and copper lodes.

14. *Tremolite.* This is a mineral of late discovery in St. Just. I have seen only two specimens of it, which came from the rocks below Botallack. They are of the asbestiform kind, and of a brownish white colour.

15. *Asbestus* is of frequent occurrence in minute fibres, in the slate rocks of St. Just; but in the vein of prehnite which has been lately discovered, some very fine specimens have been found, with nodules of prehnite imbedded in it. That variety called *mountain-cork* has occurred in conjunction with axinite, in Roscommon cliff.

16. *Mica.* This is interspersed in most of the granite of this parish. I have never observed it alone. In some granite which occurs in the tin lode of Huel Bill, the mica predominates over both the quartz and the felspar.

17. *Talc* has occurred, in laminæ, in the copper lode of Huel Cock.

18. *Felspar.* This mineral abounds, of course, in the granite of St. Just; and occurs in the slate rocks near Huel Castle, in rhomboidal crystals. Some specimens have been found near the same spot crystallized in oblique four-sided prisms, bevelled at the extremities on the obtuse lateral edges: these are probably adularia.

19. *Steatite,* although not common, is sometimes met with in the tin lode of Carnyorth moor, which is in granite, and in one of the tin and copper lodes of Botallack, which is in slate. In the latter it has been found enclosing oxide of iron. It is of a greenish white colour, and feels as soapy as that of the Lizard. There are

also small veins of steatite in the slate, on the southern side of Pendeen Cove.

20. *Chlorite.* Earthy chlorite forms the veinstone of several of the tin lodes in St. Just, particularly of some parts of the lodes of Botallack, where both tin and copper have been found in it: chlorite also appears to be one of the constituent parts of the rocks on some parts of the coast, especially at Chycornish Carn.

2. ARGILLACEOUS.

Pinite. This, I believe, is the only mineral found in St. Just, in which alumine predominates. It occurs in the granite rocks, on the high hills south-east of Trewellard, of a blueish grey colour, crystallized in six-sided prisms.

I am not aware of the occurrence of any minerals in this Parish of which magnesia forms the principal ingredient. I have been told that serpentine was found some years ago in the copper lode of Huel Cock, but I have never seen it, and my information is not sufficiently satisfactory to enable me to state it as a fact.

3. CALCAREOUS.

St. Just cannot boast either of its quantity, or its variety of calcareous minerals; but it is not entirely destitute of them.

1. *Calcareous spar.* This occurs both massive and crystallized; sometimes imbedded in

the slate, but generally either in separate veins in the slate, or in the tin and copper lodes. The forms of its crystals are very numerous. In Huel Bellon it has been found in six-sided prisms with flat tops. In the slate cliffs below Huel Owls and Huel Castle it has occurred in three-sided prisms, terminating in very oblique three-sided pyramids, and also in six-sided prisms, the sides almost in an acute and triangular form, with the broad and narrow extremities alternating, and terminated in three-sided pyramids resting on the acute planes of the prism. In one of the tin and copper lodes of Botallack, it has been found in hexahedral tables, obtuse hexahedrons, and circular plates composed of minute crystals, sometimes much curved and finely aggregated, and often terminated at the circumference by six-sided prisms with three-sided pyramids crossing at right angles, so as to produce the appearance of a broad wheel. Some specimens of the latter variety have lately been found, worthy of a place in first-rate cabinets. There are many other modifications, which it is not easy to describe. The hexahedral crystals have been met with coated with iron pyrites.

2. *Schiefer-spar* is found in a vein, with calcareous spar, and enclosing angular pieces of felspar, in the cliff below Huel Owls.

3. *Arragonite*, in needle form crystals, diverging, and forming botryoidal concretions, has been lately found in Huel Edward, chiefly in small cavities in black and green chrysocolla.

4. *Pearl-spar* has been found in the copper lode of Huel Castle, and also in a vein of calcareous spar in the cliff under Huel Owls; sometimes in transparent rhombs, at others, pearly and opaque, and occasionally botryoidal. It is of a fine flesh red and white colour. This mineral has also occurred imbedded in the slate.

5 *Fluor*, of a fine purple and green colour, forms one of the vein-stones of copper in Botallack, where some rare crystals of this mineral have been found. Mr. Fox has a specimen in hexahedral prisms terminating in very obtuse six-sided pyramids: the prisms are about the size of a crow's quill, and are from ¼ to ⅜ of an inch long: the colour varies from violet to grass green, and in some lights it appears of a brownish red colour. It does not crackle on a hot iron, or before the blow pipe, and in this respect it resembles chlorophane.

6. *Apatite* is new in St. Just; but it is now found, of a yellowish green colour, crystallized in hexahedral prisms, in the slate rocks between Botallack and Huel Cock: and also, of a greyish white colour, united with hornblende, in the cliffs of Huel Cock Carn.

Here ends, for the present, my enumeration of the minerals found in different parts of St. Just*; but as so many species and varieties, before unknown in that Parish, have been discovered within a very short period, and as a large part of it has never yet been properly explored, I am confident that, in a little time, the list may be considerably enlarged. It already contains, however, several minerals which I believe have not been met with in any other part of this county; and of other minerals, already known in Cornwall, some varieties are peculiar to this Parish: viz. scaly red iron ore, red chalk, black iron ore, jaspery iron ore, some crystallizations of spathose iron ore, native bismuth, cupriferous sulphuret of bismuth, prehnite, stilbite, mesotype, and mountain cork.

Besides those which I have attempted to describe, several others are known even now; but without a name. One of them answers pretty nearly to the description of Zoisite, and another to that of Lithomarga. The locality of the former I have not exactly ascertained: the latter was found, with grey sulphuret of copper, in Botallack.

* I must here acknowledge my obligation to Robert W. Fox, Esq. for his kind communications. In the course of a short residence in this neighbourhood for the benefit of his health, he explored a large part of St. Just, and discovered several minerals not previously known in that parish.

This catalogue of minerals has a more immediate concern with the mineralogist. I now proceed to mention some facts which may attract the attention of the geologist.

1. *Junction of the Granite and Slate.*

It will be seen by an inspection of the Map which accompanies this Paper, that the whole of St. Just consists of granite, except in the north-western part, where the slate overlies the granite, and extends from the coast, in some parts a quarter of a mile, and in scarcely any part more than half a mile inwards; but it is only at the commencement and the termination of the slate, that the junction of the two substances is visible. At Pendeen Cove, the northern point, the slate overlies the granite at an angle of about 45°. The line of division of the two rocks is here very distinct. In the cliff, the slate has the appearance of having been separately deposited on the granite; but in the rocks on the beach their connexion is very close: the granite here is more quartzose, and the slate more micaceous than at a distance from the junction. At Porth Just, the southern point, the underlie of the granite is not nearly so great, and between the two bodies is a vein of quartz which forms the tin lode of Little Bounds mine. The principal mines are

nearly on the line of junction, and there are not many which are more than a mile distant from it.

The junction of those two rocks greatly affects both the tin and copper lodes. The tin lodes are generally richer in the granite than in the slate, but richest when they are immediately between the two rocks, one of the walls being granite, and the other slate. In such cases they frequently extend into large floors, of which some remarkable instances have occurred in Botallack and at Chycornish. It will be seen by reference to the Map that in this mine two lodes, viz. Coffin Crista lode and Huel Hazard lode, fall in with each other just at the junction of the granite and slate, at the spot called the Bunny; and here were found those productive tin floors which will be presently described. Now although the rich bunches which are generally found at the junction are not the only rich parts of the tin lodes, yet on the question of setting an old mine at work, or of exploring an untried spot of ground, in this part of St. Just, the preference would naturally be given (all other circumstances being equal) to a spot in which the lodes are likely to come in contact with the junction of the granite and slate.

The copper lodes also are richest when between the two rocks, but when in the granite alone, they become nearly unproductive. The lode of Levant is in slate; that of Huel Spearn

is in granite, and those of Botallack are in both; each of these mines furnishes a proof that slate is more favourable to copper lodes than granite.

The general composition of these slate rocks has been already mentioned in the account of siliceous minerals.

2. *Granite Veins.*

There are four points in St. Just, in which granite veins may be seen intersecting the slate; viz. Pendeen Cove, Chycornish Carn, Polladan Cove, and Porth Just; and I believe some of the veins near Whitsand Bay are within the limits of this Parish. These veins have been already noticed in a Paper on the relative age of the veins of Cornwall, and most of them have been described by Dr. Forbes in his Paper on the Land's-end district, both of which are inserted in the former part of the present Volume: I will therefore only add, that as in the different places above mentioned, they appear in different circumstances, with relation to the containing rocks, the Geologist may minutely examine, and form his own theory respecting them.

3. *Rock Veins.*

These also have been described in the paper already alluded to: it will therefore be sufficient merely to enumerate them and mention their localities.

1. Veins of quartz, in almost every part of the coast.

2. Veins of prehnite, in the cliffs between Botallack and Huel Cock.

3. Veins of axinite, in Roscommon cliff.

4. Veins of actynolite, in the rocks near Cape Cornwall.

5. Veins of epidote, in the Crown rock at Botallack.

6. Veins of garnet-rock in the same place.

7. Veins of steatite, in Pendeen Cove.

8. Veins of calcareous spar, in the cliffs below Huel Owls, and Huel Castle.

All those veins, with the exception of some of those of quartz, are in slate.

4. *Metalliferous Veins.*

In the lodes of St. Just there are some peculiarities which deserve notice.

1. *Their direction,* which, as will be observed in the map, (see Plate VII.) is generally about south-east and north-west; a direction different from that of almost all the other tin lodes of Cornwall. It is indeed the usual direction of the contra copper lodes, which are supposed to be more recent than either the tin lodes or the east and west copper lodes. In two of the lodes of Botallack, viz. Huel Button lode and Coffin Christa lode, the direction is north and south: these, with a few others in this Parish, are the

only instances I have heard of, except at Polgooth, in which tin-lodes have the same direction as cross-courses.—2. *Their underlie.* Almost all the lodes which are situated in the northern part of St. Just (north of the valley of Nancherrow) underlie towards the south, whilst most of those in the southern part underlie northwards. If therefore, as one of the miners jocosely observed, it were possible to go deep enough, the point might be discovered where almost all the lodes meet.—3. *The apparent cause of their riches.* The tin-lodes (except in cases where two or more lodes meet) are rarely rich, unless where very minute metalliferous veins, called *feeders*, strike into them on either side: in some cases they join them on their underlie, and in others on their vertical direction.

There is no part of Cornwall, I presume, so favourable to an examination of the upper parts of both tin and copper lodes, as the north-western part of this parish: the large extent of coast affords excellent opportunities of observing them. Amongst those which are represented on the map (probably not a fourth part of the whole) I will merely point out the lodes of Huel St. Just, and Little Bounds, which are in granite; and those of Praze, Huel Castle, Huel Edward, Parknoweth, Botallack, Huel Cock, Levant, and Zonebrinny, which are in slate: these are all

visible in the cliff, with many others which do not appear ever to have been wrought.

It is stated in the before-mentioned Paper that there are in St. Just some large cross veins, called by the miners *guides*, because they expect by following them to be guided to the tin and copper lodes. These guides are in fact iron lodes, in which most of the ores of iron described in the former part of this paper have been found. They are about six feet wide. I am not aware of the existence of any other similar veins in Cornwall. One of them has been traced to the coast not far from Castle Treryn, a distance of five miles: another has been traced upwards of three miles. Some of those veins also may be seen on the coast of the northern and north-western parts of St. Just.

5. *Intersection of Veins.*

The intersections of tin lodes with each other, and with the iron lodes (or *guides*), longitudinally, are said to be either productive of riches or the contrary, according to the angle at which the lodes meet each other: the smaller the angle, the more promising is the intersection. Long experience has enabled the miners of St. Just to fix as a kind of standard an angle of 45°. If two tin lodes, or a tin lode and an iron lode, meet at a larger angle than this, little expectation is formed of a beneficial result; but if it be

smaller, especially if from 20 to 30°, the miners are confident of finding a bunch of tin at the junction. In fact, when the veins meet each other at a small angle, they generally unite, and continue together for several fathoms. It is from this union that the miner expects the riches. When the angle is large, the veins generally cross each other, and separate immediately. There are exceptions to this rule; but it will be found to hold good in general. The richest part of Botallack, which they call the Crowns, or Crown lode, is at the junction of Huel Button lode with the narrow *guide:* as that lode is rather a copper than a tin lode, a rich bunch of copper ore was the consequence of its union with the *guide*. The junction of Parknoweth lode with the same *guide* produced an immense quantity of tin*; as did also the junction of the same lode with Huel Ludgvan tin lode: on the contrary, the tin lode of Huel Owls was rich till it met the *guide*, which intersected, without uniting with it, and there

* It is said that the *guide* is here carried 60 fathoms on the direction of the tin lode. If this is really the case, it presents a singular exception to the general order of the veins of Cornwall. As this mine is likely to be set at work again, this fact will be either established or confuted. From the direction of the shafts on the surface, the *guide* certainly appears to have altered its direction just at that spot. There are however some reasons to doubt its being carried out of its course by the tin lode, as the latter has never been found on the other side of it: it must therefore have been broken off by the *guide*. It appears too that this guide traverses the other tin lodes which it meets with, and frequently heaves them.

its riches ceased. I have not met with any intersections of lodes producing copper alone. Except in the case of Levant, most of the copper is found in lodes which also produce tin, and it is difficult to fix their proper station amongst veins. When the tin, or tin and copper lodes, fall in with the iron lodes, they are frequently carried for some distance in the direction of the latter; and it is to be supposed, that on separating, they go off in their own previous direction; but this has not been often ascertained, as very few lodes which have been heaved, or carried out of their own direction by the iron lodes, have been found, or properly sought for, on the opposite side. The two lodes, whilst together, appear as one productive lode: the iron-stone of the iron lodes becomes, in such cases a veinstone both of tin and copper.

It is very difficult to ascertain whether the tin lodes of St. Just are of different ages: they often intersect each other, but so little attention has been paid to these circumstances by the miners, that it is almost impossible to get at the truth.

6. *Minerals imbedded in the rocks.*

These are, garnets at Chycornish Carn; asbestus below Huel Cock; axinite in Trewellard Cliff; shorl near Botallack; felspar in the rocks below Huel Castle; calcareous spar in the same

place, and in Roscommon cliff; apatite near Botallack; arseniate of cobalt in the Crown rock; and pinite in the granite on the hills above Trewellard. All these, except the pinite, are imbedded in slate rocks. It will be at once perceived that the slate country is far richer than the granite, with respect to the number and variety of its minerals, whether they are found imbedded in the rock, or in separate veins, or in the copper and tin lodes. This district therefore presents another advantage both to the mineralogist and the geologist, over every other part of Cornwall, (except perhaps the Lizard,) as all the minerals which occur either in the rocks or the rock-veins, may be viewed in all their situations, positions, and connexions.

7. *Floors, or Horizontal Beds.*

St. Just abounds in floors of tin, more than any other part of Cornwall.

In that part of the tenement of Trewellard which is in a slate country, some tin-floors have been wrought near the surface; the deepest is only seven fathoms below it: they were from one to two feet in thickness, and perhaps twenty feet in diameter*; they occurred at the junction of several tin lodes.

* It must not be supposed from this description that the floors are round: on the contrary they are frequently very irregular, but their surface is about as large as would be comprized in a circle of 20 feet diameter.

In Huel St. Just, a mass of tin-ore, of a very singular nature, was discovered some years ago, which appears to belong to the floor formation. It first appeared at the depth of seventeen fathoms under the sea, and has been followed downward, about ten fathoms. It was seven or eight feet in diameter. At the top, it was on the south-western side of the tin lode; but it inclined in a very small degree, until it was almost wholly on the north-eastern side of the lode. The cavity in which it was found had the appearance (after the tin was taken away) of a large underlying shaft, closed at the top. The most remarkable circumstance, however, relates to the state in which the tin ore was found; instead of being a solid body, as in usual in floors, it appeared (as the miners termed it from whom I received the account) like a heap of *attle*, or rubbish; just as if it had been thrown in that state into the cavity. The fragments were not rounded, but had all the appearance of the broken tin-stone which is generally seen on the surface of tin mines. The top of this mass of ore was about three feet below the granite top of the cavity, as if it had sunk by contraction or pressure. One of the miners told me that he found sufficient space between the granite covering and the ore, to sit upright on the latter. In its present deepest part, it is not so wide as it was at a higher level; but it is

of lodes in the space where they occur. In other parts of this mine, solitary floors have been found at different depths, on one of which, at 22 fathoms under the surface, the miners are now at work. It is about nine feet in diameter, and nearly round. They have seen its extent, and have found the country both above and below it (for it is quite horizontal,) to consist of a very hard granite rock.

These floors have generally been regarded as the result of the union of several lodes. This however is cutting a knot which is not easy to untie. As some floors have been discovered where no union of lodes has taken place, such a union does not appear absolutely necessary to their formation. In the case of a single floor of tin, not larger than those which have been described, its formation may perhaps be accounted for on the same principles as the formation of all true veins; but where there is a succession of floors, if a junction of lodes could be satisfactorily shewn at every point where they occur, it would give us little assistance in forming a theory of their formation. We have been accustomed to consider the contents of the tin lodes as of posterior formation to the rocks which contain them; but here is a succession of beds, all of them connected with tin-lodes, (for they are always found on one or both sides of tin lodes, to which, when they are not

quite close, they are united by a small branch,) and yet alternating with the rocks of the country, which are supposed to be older than the tin lodes. It is not surprizing that the practical miner troubles himself little respecting the theory of the formation of the metalliferous bodies which he may discover; but it is indeed extraordinary (as Mr. Hawkins has observed in his paper on tin-floors,) that in a district where so large a quantity of tin has been found in floors, there is not more diligence and perseverance evinced in searching for those deposits.

8. *Stream-works.*

It would be rather extraordinary if a district abounding in tin, like St. Just, should be destitute of tin stream-works. Several of these were formerly wrought in this Parish; but the principal of them have been long since abandoned. Pillianeth and Pemeder stream-works were formerly very extensive and productive; but they have not been wrought within the memory of any person now living.

Dr. Borlase gives an account of a remarkable stream in this Parish, which I shall relate in his own words. " In the tenement of Douran, in " the year 1738, there was a very singular stream " of tin discovered: the ore was pulverized, be- " tween one foot and one foot and half in depth " or thickness, of various breadths. In the

"moory ground where it was first discovered, it "had a back of soil and gravel over it, only two "feet high, but as the stream advanced farther "to the east, it had still a higher covering, till at "last it had all Douran hill (which may be "about forty feet perpendicular) over it, the "stream continuing still its horizontal position."

There are three small streams now at work, but their produce is small. 1. Leswhidden Moor. Here the alluvial soil is from six to nine feet deep above the shelf. 2. Bostraze Moor, where the soil is nearly of the same depth as at Leswhidden Moor. 3. Numphra Moor. The alluvial soil here is not nearly so deep as at the other stream-works: on an average it does not exceed five feet. In all these streams, the pebbles and pulverized matter containing the tin, are mixed indiscriminately with the lower part of the muddy and gravelly deposit. I have not heard of any gold, or wood-tin, having been found in either of them.

The theory of the origin of those alluvial deposits termed tin-streams, although it is perhaps not attended with so many difficulties as that of tin-floors, is yet very far from satisfactory. The freedom of stream-tin from any connexion with other metals except iron, and that in a very small degree;—its superior purity to the tin of the lodes;—the very small quantity, and the inferior quality, of tin which is usually found in

lodes near their present surface,—and, above all, the existence, in most stream-works, of veined fragments called wood-tin, and of spathose tin-ore, which we have no good ground to suppose have ever been found in the lodes, are facts rather contrary to the supposition that the tin of the streams was, at some period, washed from the upper part of the lodes; and yet it must be acknowledged that there are no tin streams, except in the neighbourhood of tin lodes. In fact, this is a subject which deserves far more investigation than it has yet received, and is well worthy of the attention of those Members of the Society who reside in the vicinity of stream-works.

The value of a stream of water in a mining country is no where more obvious than in St. Just. The stream which flows from Bostraze to the sea, turns the wheels of seventeen stamping mills and three grist mills.

9. *Formation of Sandstone.*

In Pendeen Cove, which forms the northern boundary of this Parish, the sand consists principally of comminuted shells, mixed with particles of slate, and of the constituent parts of granite. The cliff which bounds the cove is rather precipitous, and in one part consists of large fragments of granite imbedded in clay and earth. The interstices of this cliff are filled with sand,

(probably blown there from the beach by high winds;) which is exposed to the percolation of water holding in solution the oxide of iron, whose cementing property is well known. The sand is thus gradually becoming stone, and in some parts of the cliff it has already acquired considerable hardness.*

In the cliff near Little Bounds mine, the same operation is going forward, but the sand is more granitic than at Pendeen Cove.

There are other objects worthy of notice in St. Just, which it may be proper to mention, although some of them refer to other sciences.

10. *Precipitation of Copper.*

This belongs rather to the chemist than the geologist. It is carried on, on a very small scale, on the bank of the river which runs into the sea at Pendeen Cove, on the spot where the stamping mills and burning houses (or roasting furnaces) belonging to Botallack mine are situated. The tin-ore of Botallack is generally mixed with a portion of sulphuret of copper, which is not separable from it by dressing. The ore is reduced to powder in the stamping mill, and on being put into the roasting furnace, the cop-

* As this sand appears in some cases to extend further than the face or the interstices of the cliff, some have supposed a body of it to have covered the ancient surface, either by the means of high winds, or other causes, before the superincumbent mass of clay and granite fragments was placed there.

per, by attracting the oxygen of the atmosphere, becomes an oxide. The sulphur uniting with the oxygen forms sulphuric acid, which makes the copper a sulphat instead of a sulphuret. When taken out of the furnace, the roasted ore is exposed to the air, by which a further quantity of sulphat is formed by the attraction of the oxygen from the atmosphere: the whole is then well washed, by which the sulphat of copper is dissolved in the water. This water, which is of a blueish colour, is poured into casks, in which are placed pieces of iron: these are first oxydized by the oxygen of the water, and then by the superior affinity of the sulphuric acid to iron than to copper, the former is dissolved, and the latter precipitated, either in the metallic state, or in the state of an oxide: I have several times found bits of pure copper in the precipitate*. The quantity of copper procured in this way in Botallack, is about a ton in a year. The water holding the copper in solution must be of considerable strength, as thin new hoop-iron is dissolved in it in thirty hours, and iron of the thickness of a quarter of

* This mode of obtaining copper is now practised in most of the mines in which the tin-stone is mixed with copper ore, as in Dolcoath, Cook's Kitchen, Chacewater, and in some parts of St. Agnes. I believe there is not now a single instance in the whole of Cornwall, of copper being precipitated from the waters which flow through the copper lodes, although this operation was formerly carried on at Chacewater, and at Huel Crafty. The copper ores of Cornwall are, in general, less sulphureous than those of almost any other country.

an inch, in a fortnight. In order to ascertain the comparative quantities of iron dissolved and copper precipitated, the Agent of Botallack immersed in the water 140lbs. of iron, which remained in it about six weeks, during which period the water was changed as often as its strength was supposed to be exhausted. The remaining iron was then taken out, and found to weigh 40lbs., leaving 100lbs. to have been consumed in the operation. At the bottom of the cask was found 240lbs. of precipitate, which yielded by assay 75 parts in 100, of pure copper. The quantity of copper gained therefore, was 180lbs., and of iron lost, 100lbs.: but it must not be supposed that all this iron was dissolved, for had an analysis of the precipitate been made, no doubt the remaining 25 parts would have been found to consist principally of iron and oxygen. It appears, therefore, that the copper precipitated was at least double the quantity of iron dissolved.

This result is very different from what might have been expected, according to Dr. Wollaston's Scale of Equivalents, in which iron and copper bear the same proportion to each other, as the numbers 42 and 50. It is probable therefore that the experiment was not correctly made.*

* I requested the Agent, some time ago, to make another trial with great care and caution; but he has not yet completed it.

11. *Submarine Mines.*

These are objects rather of curiosity than geology; but they are singular, and therefore merit a description. Mr. Hawkins has given, in the preceding volume, an account of the principal submarine mine in Cornwall; viz. the Wherry; the only one of which the entrance is actually through the sea. Many of the mines of St. Just are on the border of the land, and some are on the very edge of its precipitous termination, and are wrought to a considerable distance under the sea; but all communication to them is from the land.

1. *Levant Copper Mine.* The first level in this mine is about 17 fathoms below high water mark, and is extended 40 fathoms in length under the sea. As the shore declines rapidly, there can be scarcely more than 10 fathoms between the end of the level and the sea. In one part of it the workmen, tempted by a bunch of copper ore, followed it to the height of five fathoms above the level, but feared to proceed further. There is a deeper level, 28 fathoms under high water mark, which has been driven 26 fathoms under the sea. Not only the roaring of the sea in stormy weather, but the ordinary breaking of the waves on the beach, is distinctly heard by the miners. The water in this mine is salt; but there is so little of it that, although the depth is 42 fathoms, the whole is

drawn to the adit in a bucket, by the labour of two men.

2. *Tolvaen Copper Mine.* The levels of this mine are known to have been extended under the sea; but at it has not been wrought since about the year 1754, I cannot obtain any particulars respecting it.

3. *Huel Cock Copper Mine.* This mine has not been wrought for several years; but I have collected the following particulars from an old miner. The *mouth* of the adit is very little above high-water mark: at very high tides the sea flows into it. At the depth of about 20 fathoms, a level is driven nearly 100 fathoms in length under the sea: the depth of the sea at that distance from the shore I am not acquainted with; but the space between the bottom of the sea and the end of the level must be very small; perhaps not more than five fathoms. In stormy weather, the thundering noise of the sea, and the concussion caused by the heavy waves dashing against the rocky beach, were so terrific that the affrighted workmen would sometimes fly from the spot, supposing the sea was actually breaking into it. In one part of this level the miners followed a bunch of ore about 12 fathoms above the level, and would have pursued it still farther, had not the agents seen the danger and forbidden them. About 40 fathoms under high water mark, another level is driven under the

sea, about 30 fathoms in length, and the whole of the lode between this and the higher level is taken away. At 20 fathoms deeper, or 60 fathoms in all, a third level is driven about the same distance. Even in the deepest part, the workmen could distinctly hear the noise of the waves. The water in every level was very brakish, and was drawn to the adit by a small water engine.

4. *Botallack Tin and Copper Mine.* This mine was wrought under the sea beyond the memory of any person now living. The ancient workmen have indeed left a convincing proof of it by having followed the ore so high as to open a communication between the sea and the mine. Whether this opening was made whilst they were at work, or the sea afterwards broke through the thin barrier which was left, is not known; it is, however, now stopped by a wooden platform, on which is laid a mass of slimy turf, and the whole is covered by the stony fragments of the beach. At about half spring, the sea flows over it at every return of the tide.

At present, the first level on the Crown lode is about 30 fathoms below high water mark, and is driven 30 fathoms horizontally; the 40 fathoms level is driven 10 fathoms,—the 65 fathoms level, 30 fathoms,—and the 85 fathoms level, 40 fathoms,—all under the sea. In the highest level, the noise of a heavy sea beating against

the rocks is frequently sufficient to terrify the workmen, and even in the deepest part it is distinctly heard. The water is brakish, but not so much so in the lower as in the higher levels. A singular circumstance occurs in the 40 fathoms level: a small quantity of clear fresh water oozes out at one spot, whilst all the water around it is salt: this is perhaps conveyed in a small vein of which the most penetrable part does not come in contact with the sea.

On Huel Button lode, also, there are two levels at the depth of 40 and 50 fathoms below high water mark, in which the lode has been pursued under the sea; in the former about 20, and in the latter 30 fathoms in length.

Although the depth of this mine is 105 fathoms below the adit, the whole of the water drawn by a small steam engine does not exceed 40 gallons per minute.

Botallack mine is now become one of the Lions of Cornwall, and is an object of as much enquiry, attention, and admiration, as either the Land's End or the Logan rock; but as its singular situation and romantic appearance have been the subjects of Dr. Paris's pen in his "Guide to Mount's-bay," I shall not attempt to add to the effect of his description.

5. *Huel Castle Copper Mine.* This mine has been wrought in a very limited way. The extent which has been explored under the sea

does not exceed ten fathoms, and in that space nothing has occurred worthy of particular remark.

6. *Praze Tin Mine.* Here, at the depth of 20 fathoms under high water mark, a level has been driven about twenty fathoms in length under the sea. This mine, however, has not been wrought for more than forty years; I am therefore obliged to dismiss it with this short notice.

The mines already mentioned are all in slate; and the small quantity of water which is found in them proves the superior compactness of this slate, as well as of the veins which it contains, to the killas and the veins of most other parts of Cornwall.

7. *Little Bounds Tin Mine.* Here three distinct lodes, distant from each other, have been wrought under the sea; two of them are in granite; the other is in slate. Here also, at some former period, through the avarice or carelessness of the workmen, a communication was made in two parts of the lode known by the name of Saveall's lode, between the sea and the mine: one of them is about high water mark at spring tides; the other is covered by the sea at every tide, except at very low neaps: great and constant attention is therefore paid to the latter, which was at first stopped by a piece of wood covered with turf; but as this was found

not to be perfectly secure, a thick platform, caulked like the deck of a ship, is now placed on it, which renders it almost water proof.

On Little Bounds lode, the 20 fathoms level below the adit is driven 40 fathoms horizontally under the sea: the other levels to the depth of 64 fathoms are driven various lengths, from 30 to 60 fathoms. On the north lode the 40 fathoms level is driven 40 fathoms, and on Saveall's lode (in slate) the levels are extended from 10 to 40 fathoms under the sea. The breaking of the waves is heard in all the levels; but as a part of this mine is under a pebbly beach, the rolling of the large pebbles, in boisterous weather, causes a more terrifying noise, and a greater concussion, than are produced by the mere dashing of the waves against the rocks. The water is all brackish, and, of course, injures the pumps. It is drawn by a water engine which is erected on the very extremity of the cliff. The situation of this mine, although not quite so romantic as that of Botallack, is yet well deserving of attention. Mr. Lysons considered it worthy of an engraving in his Magna Britannia.

Small quantities of tin-ore are frequently thrown up by the sea, on the beach below the Little Bounds engine. One or more workmen may generally be seen, on the return of the tide after high water, searching for tin amongst the

sand and shingle. It is probable that this comes from the back of some of the tin-lodes which run under the sea.

8. *Riblose Tin Mine.* The lode of this mine (which is not now at work) has been pursued across a small creek near Caraglose Head. The cavities in the granite cliff, from which the upper parts of this and other lodes have probably been washed away by the sea, have a very interesting appearance.

9. *Huel St. Just Tin Mine** is the last submarine mine which I have to notice. It is wholly in granite, and furnishes another instance of the dangerous consequences of approaching too near to the sea, whilst in pursuit of the treasures of the earth. In one part of this mine, the sea broke into the cavity from which the lode had been taken away too near to the surface. There are only two levels in this mine below high water mark; one at the depth of 17, and the other, 27 fathoms: the former has been driven 30, and the latter 35 fathoms in a horizontal direction under the sea. The water, as in the other mines, is very brackish. This mine has not been wrought for several years; but is now about to be again set at work.

* This mine is situated in Pornahvon Cove, on the northern side of which, in the centre of the cliff, far above the sea, are several strata of pebbles and sea-sand, which are covered by a considerable part of the hill. These have been particularly described by Dr. Borlase, Nat. Hist. page 76. The sand in some parts of this cove is gradually indurating.

I have no doubt that several other lodes in this Parish have been wrought under the sea, although, perhaps, not within the recollection of the present race of miners.*

* Perhaps a short notice of the other submarine mines of Cornwall may be acceptable to the Society.

1. *Huel Providence Copper Mine* (not now at work) is the first which occurs on the north coast, and is situated between St. Ives and Hayle. Here there are two levels at the depth of 24 and 32 fathoms under high water mark, both of which are driven about 20 fathoms under the sea. The water was not salt, and the workmen could scarcely hear the noise of the waves.

2. *North Battery Tin Mine.* This small concern, near St. Ives Head, has been recently set at work, and at seven fathoms deeper than the sea a level is driven about 20 fathoms under it.

3. *Bray Tin Mine*, in Towednack. Of this mine I have not obtained any particulars.

4. *Treen Copper Mine*, in Zennor. The shaft of this mine is sunk in the rock on the edge of the sea, so near to high water mark, that at very high tides the sea would beat into it: a strong shaft of masonwork has therefore been erected on the rock, to the height of ten feet. The only level in this mine is about 13 fathoms below the sea-level, and this is driven 20 fathoms eastward, and 10 fathoms westward of the shaft, which is so situated that the sea flows into a creek on each side of it. The water is a little brackish, and is drawn by a wind.

5. *Huel Speedwell Copper Mine.* Although this is an extensive mine, only one level has been driven under the sea, about 30 fathoms horizontally, at the depth of 30 fathoms below high water mark. The noise of the sea is seldom heard in it.

6. *Huel Rose Lead Mine*, near Porthleven. Here the 21 fathoms level is driven 10 fathoms,—the 26 fathoms level, 15 fathoms,—the 36 fathoms level, 30 fathoms,—and the 42 fathoms level, 26 fathoms; all under the sea. The water was as salt as the sea-water, and as much so in the deepest, as in the shallowest level. The roaring of the sea could scarcely be heard by the workmen. This mine has not been wrought for several years.

It is worthy of remark, that the noise of the waves is much more distinctly heard by the miners where the rock is very compact, such as the hornblende-rock of the St. Just mines, than where it is not so hard; but tough and slaty, such as the clay-slate of Huel Providence, Huel Speedwell, and Huel Rose.

12. *Ancient mode of Mining.*

It is probable that, for several ages after the commencement of mining, all the operations were open to the sun; a mode of mining which is still exemplified at Carclase Mine, near St. Austle. The ore and rubbish were raised from those mines by manual labour, being shovelled from cast to cast, or, as it was then termed, from *shamble* to *shamble*, till the whole reached the top. This mode of working seems to have prevailed, in a considerable degree, so late as 1671, as appears from an anonymous paper entitled "Observations on the Mines of Cornwall and Devon," which was read to the Royal Society in that year. In the case of a lode continuing rich near the surface, for a considerable length, a large chasm would gradually be formed, which, unless filled with the rubbish of more recent mines, would remain as an evidence to after ages of the needless labour by which the miners of former times obtained the treasures of the earth. Chasms of this kind, which are called by the miners *coffins*, are still to be seen in many of the tin districts of Cornwall, as in Wendron, St. Agnes, Madern, Gwinear, &c. The largest I have heard of was at the Sealhole mine in St. Agnes: it extended nearly half a mile in length, but a considerable part of it has been filled up. There were others at Huel Unity, Poldice, Huel Vor, Godolphin, &c. within the recollection of

many of the miners; but most of them have been long since filled up. In fact, the miners are glad to meet with such reservoirs for their *deads*, or rubbish.

Several of these chasms, or *coffins*, are still visible in different parts of St. Just, viz. at Trevagean,—Huel Diamond,—Bartinney Hill,—Carnleskis,—Huel Dower,—Truthal Moor,—Praze, &c. All these are on the *back* of lodes; and that many others formerly existed, there is sufficient evidence in the names of other lodes, as Coffin Crista,—Coffin Carrarack,—Coffin Garrow, &c. That the floors of tin were anciently wrought in this manner, Botallack still affords indubitable evidence: at the Bunny, where they principally occurred, there still remains a chasm about 20 fathoms in length, and nearly as many in width.

Those lodes and floors were, in all probability, anciently wrought by *shambles;* and with respect to the quantity of water, no part of Cornwall could have been more favourable to this mode of working; for both the slate and the granite country are so compact, that there is much less water at a given depth, than is found in most other mining districts. Until the year 1801, not a single steam-engine had ever been erected in St. Just.

Connected with the ancient mode of mining is the ancient method of preparing the tin. Se-

veral circular granite stones, from two to three feet in diameter, have been, from time to time, found in different parts of St. Just; generally in vallies, or on the banks of rivers. One of these has been presented to the Society by Mr. Chenhalls, who stated that it was a mill-stone which was formerly used for grinding tin-ore. That this mode of pulverizing tin-ore actually obtained in Cornwall appears, not only from Carew's description, but from a Paper, by one Dr. Cotton, which was read to the Royal Society in 1664. These mill-stones are reported to have been worked by horses.

I trust the Lords of the soil, and the mining proprietors of St. Just, will pardon my presumption, if I take the liberty to express my opinion that the present mode of mining in that parish is very defective, and may be considerably improved. In the first place, it appears to me that when lodes are found to be intersected and heaved, by cross-veins, far too little search is made for their corresponding parts. Unless they are speedily, and without much expense, discovered on the opposite side of the intersecting veins, the search is relinquished. In some cases, I believe, no attempt whatever has been made to discover the lost segment of the lode. 2. If either of the levels in a mine becomes unproductive, it is generally abandoned far too soon. A lode which has been rich in

any level, and has become poor, ought to be explored at least 50 fathoms from its productive part (unless it be uncommonly hard) before it is abandoned. 3. The *sump*, or bottom of the engine shaft, (or, where there is no engine, the shaft from which the water is drawn to the adit,) should be invariably the deepest part of the mine; but it is not uncommon, if I am correctly informed, to sink, in many parts of the mines, several fathoms deeper than the *sump*, by *winzes*, and to draw the water from those excavations to the *sump* by manual labour. I have heard of bunches of tin being pursued to the depth of 40 fathoms, entirely by *winzes*, in which the work was carried on either vertically, or horizontally, or at intermediate angles, according to the direction of the bunch. By such methods, the Adventurers must pay much more than it would cost them to obtain the ore by a better mode of working; and the property of the Lords of the soil cannot be properly explored. 4. The *sump* (even where it is the deepest part of the mine) should be kept more constantly and regularly at work. I believe it is not an unfrequent practice, when the *sump* is sunk sufficiently deep to commence a new level, to suspend its further progress, until the level becomes nearly exhausted. This is not good policy; it is frequently the cause of the sudden and total abandonment of a mine; for if the

level becomes suddenly poor, the Adventurers are dispirited, and disinclined to lay out a considerable sum of money to open another level. Whilst other parts of a mine are productive, the *sump* may be sunk at the expense of manual labour alone; but when the levels are exhausted, the expense of draining the water must be added to that of labour, in order *to sink the sump.* 5. It would probably be useful and profitable, if, after the manner of mining in other parts of Cornwall, the workmen were more frequently to explore a few fathoms in a north and south direction from the principal lodes, with a view of discovering parallel or side lodes, which are often found to exist near master-lodes. It is to a discovery made by the adoption of this method, that Huel Vor, now the principal tin mine in Cornwall, owes her existence: it is peculiarly worthy of adoption in St. Just, as it may tend to the discovery of tin-floors, as well as of parallel tin-lodes. 6. The grand desideratum for the extension of mining generally, in the Parish of St. Just, is an adit whose direction shall be from north to south, or vice versa. As most of the lodes run nearly south-east and north-west, and are therefore visible on the coast, the adits, in general, are commenced and continued on the course of the lodes: no other lodes therefore are likely to be discovered in their progress; but if an adit were commenced a few feet above

high water mark, at the termination of the valley called Nancherrow Bottom, and were carried up the valley as far as Nancherrow, or even as far as the village of Carnidjack, and from thence driven northward and southward, it would cross most of the lodes in this extensive parish, and would probably discover some, whose treasures would amply remunerate the Adventurers. It is by the adoption of a method of this kind, that the Parish of Gwennap is become the principal mining district in Cornwall.

The miners, however, state in their own defence, that the great hardness of the country is often unfavourable to their speedy progress, and in some cases, prevents the accomplishment of their wishes and intentions; but it is evident that, either from the causes which I have mentioned, or from others, a district which abounds in metalliferous veins is so far from being generally and properly explored, that the mining operations at present carried on, are almost wholly confined to a small slip of land parallel with the coast.

13. *Antiquities.*

In the conclusion of a description of St. Just, it may not be wholly unappropriate to mention a few relicts of antiquity, which may still be seen there, although they have little concern with geology. The Geologist may perhaps be an Antiquarian,

1. *Rock Circles.* Dr. Borlase considers the Botallack circles as some of the most important in Cornwall: they appear to have been three or four in number, but they run into each other: they are composed of small stones; but so many have been carried away that, although a stranger, on their being pointed out to him, might easily trace their circular form, he would otherwise, perhaps, pass through them without being aware that he was treading on ground which our learned Historian considers as having been consecrated to Druidical worship.

2. *Amphitheatre.* This is considered by Dr. Borlase as British, and as intended for sports, athletic exercises, and single combats. It adjoins the village called the Church-town, and is in a tolerable state of preservation.

3. *Cromleh.** Chun Cromleh stands on the very line which divides this parish from Morvah. It consists of a large flat stone which was supported by several upright stones, but is partly fallen on one side. It is supposed to denote the place of sepulture of some Briton of rank. There is now I believe not more than one Cromleh remaining in its original position, in the western part of Cornwall.

* It is not generally known that there are two Cromlehs at Lanyon, in Madern, one of which was entirely overlooked by Dr. Borlase, nor has it, I believe, been mentioned by any succeeding Historian. It is situated about a quarter of a mile westward of Lanyon House, on the declivity of a hill. It is nearly as large as that which is emphatically

4. *Rock Basins.* These may be seen at Bosworlas, where one of them is still called the Giant's Chair. Dr. Borlase supposes they were made by art, and were used by the Druids in their sacrificial rites. Very few, however, are now of this opinion. I am fully persuaded that these cavities are the result of the natural decomposition of the granite rock, by the action of the air and water conjointly.

5. *Caves.* Pendeen Vau, or Cave, appears to have been one of those hiding places in which the Britons secreted themselves, and their property, from the Saxons and Danes. It is still almost entire, which is greatly owing to the superstitious fears of the inhabitants, many of whom have still a dread of entering it.

6. *Cliff Castles.* There were formerly two of these places of defence in St. Just, viz. Carnidjack, and Boscagel Castles. The remains of the former are still to be seen, but those of the latter are nearly obliterated. Their entrenchments were only towards the land, and they are generally supposed to have been the work of the invading Saxons, or Danes.

called "Lanyon Cromleh." Dr. Borlase says (Antiq. page 224), "I find the number of supporters, in all the monuments of this kind "which I have seen, to be no more than three." It is singular that the only Cromleh that escaped the Doctor's observation should have four supporters: these formed a square *Kist-vaen:* one of them is fallen down, but three are still standing. The Cromleh is fallen on its edge on the western side.

7. *Hill Castle.* On Bartinney Hill some remains of a circular entrenchment, probably of Danish origin, are still visible.

The localities of all those objects are marked on the map.

This account of the parish of St. Just will suffice to shew what a wealthy mine of science exists within a very small district, and what facilities are afforded, in the western part of Cornwall, for obtaining a considerable practical knowledge of mineralogy and geology, of which the collection in the cabinets of the Society is well calculated to illustrate the theory. It may also perhaps prove serviceable to the scientific stranger, by pointing out to him the localities of minerals which he may be anxious to obtain, and the geological peculiarities which he may wish to examine.

I must, however, in order to prevent disappointment, exhibit the unfavourable side of the picture. With respect to the external appearance of St. Just, nothing can present a more forbidding and discouraging aspect to a stranger, than the barren and rocky country on which he will enter at the distance of three miles from Penzance, and which will accompany him all the way to St. Just; and if, on his arrival there, he shall expect, from the description which I have given, to find any of the minerals so prominently situated as to salute his eyes at once;

or if he shall suppose that those objects which are especially worthy of notice in a geological point of view, are to be discovered and examined in the space of a few hours, he will be greatly mistaken and disappointed; for very few, either of the minerals or the veins, are to be found *in situ*, but by diligent, patient, and persevering search.

It is exceedingly probable that the western extremity of England, of which St. Just forms a prominent part, constituted the principal portion of what was formerly known under the name of the *Cassiterides*. The Scilly Islands have long been considered as the *Cassiterides* of the Ancients, and although Dr. Borlase and other historians suppose that the western parts of Cornwall might have been included amongst them, they still consider the appellation as peculiarly belonging to the Scilly Islands, and as justly applicable to them, on account of their large treasures of tin. It appears to me, however, that those Islands could never have been entitled to the appellation of *Tin-Isles*. In Cornwall, tin has been invariably found either in lodes, floors, or streams. In very early periods, even when the Phœnicians traded with the Britons for tin, it is probable that tin was procured from lodes and floors, as well as from streams; for Diodorus Siculus, speaking of the people that inhabited the promontory of Bele-

rium, expressly says, "These are the people "that make the tin, which, with a great deal of "care and labour, they dig out of the ground, "and that being rocky, the metal is mixed with "some veins of earth, &c." Lodes and floors, such as have been already described, whose treasures appeared at or near the surface, could scarcely have remained long undiscovered, after the inhabitants became acquainted with the value of tin-ore, and might have been wrought from the surface downward, to a certain extent, very easily, even in the days of the Phœnicians. But what is the fact with respect to the Scilly Islands? Have we any reason to believe in the existence of such lodes or floors there? Let any one examine the coast of either or of all of them, and he will quickly ascertain that their rocks contain scarcely any veins, and that, of the few which he may discover, there is not one which, in the opinion of any competent judge, is likely to produce, or ever to have produced any tin worthy of notice.

It may, however, be said that the appearance of lodes on the coast is not a criterion by which a just estimate can be formed of their riches, or poverty, in other parts; and that some tin lodes may exist, and may have been wrought in former ages, in the manner before-mentioned, although they are scarcely discoverable on the coast; or that tin might have been found in

great abundance, in floors, of which the coast could present no indication. To all this I reply that, wherever tin mines have been wrought in Cornwall, even those which are supposed the most ancient, the remains are still visible, unless they have been absorbed in the larger remains of more recent operations. I have never heard of an instance in which the miners of the present day have discovered the marks of ancient mining below the surface, which they were not previously aware of from the indications remaining *at grass*. I believe, however, that any person who will take the trouble to examine the Scilly Islands, will quickly discover that there are on none of them, any remains whatever of mines, except on one spot in the island of Tresco; and although Dr. Borlase has attached a great deal of importance to those remains, they really appear so limited, and so insignificant, as to give an idea rather of an attempt at discovery, than of the remains of extensive and permanent mining.

I apprehend therefore that the barrenness of the few veins which are visible on the coast, coupled with the absence of all remains which might indicate the existence of ancient tin mines, will render it probable that no considerable quantity of tin has been produced in the Scilly Islands, from lodes or floors.*

* I am aware that Troutbeck, in his account of the Scilly Islands, has described many of the cavernous parts of the coast as the result

If there were no productive tin-lodes or tin-floors, it will probably be allowed that there could have been no tin-streams there; for tin has never been found in streams, unless in the neighbourhood of tin lodes: we might otherwise as well search with the expectation of finding it, in the vales open to the sea in the eastern part of Devon, in Somerset, or in any other county in England, as in the western part of Devon, or in Cornwall. It is now, I believe, ascertained, that although the tin of the island of Banca is found mostly in streams, that part of the island in which these streams exist, abounds in tin lodes. It must also be observed that there are no remains whatever of stream-works, on any of the Scilly Islands.

For these reasons I am obliged to believe, in spite of the arguments of Dr. Borlase, and the reveries of a more modern Historian, that tin has neverbeen found, unless in the most insignificant quantities, in any of those islands.

I conclude then, that although the traders, whose only business was to procure tin, and who, it is probable, never penetrated beyond the coast, concluding the western part of Cornwall to be a large island, might have given the name of *Cassiterides* to all the islands within

of the operations of the tin-miners of antiquity; but a very natural question presents itself: If there were tin mines on those spots, where are the veins? they ought still to be visible, at the termination of these caverns.

their view; the tin which they procured was exclusively the produce of the main-land. If therefore it would redound either to the honour or the profit of St. Just, we might apply to her what has been said of Cornwall in general;—that her tin was probably a constituent part of the Shield and Helmet of Achilles,—the Tabernacle of the Israelites,—the Purple of Tyre,—and the Temple of Solomon.

Note. To the catalogue of minerals inserted in this paper, I have to add some varieties which have come to my knowledge since the former part of it was printed.

1. Cubic crystals of quartz, hollow, and containing water:—and also, solid cubic crystals of the same substance, probably pseudo-amorphous; from Botallack.

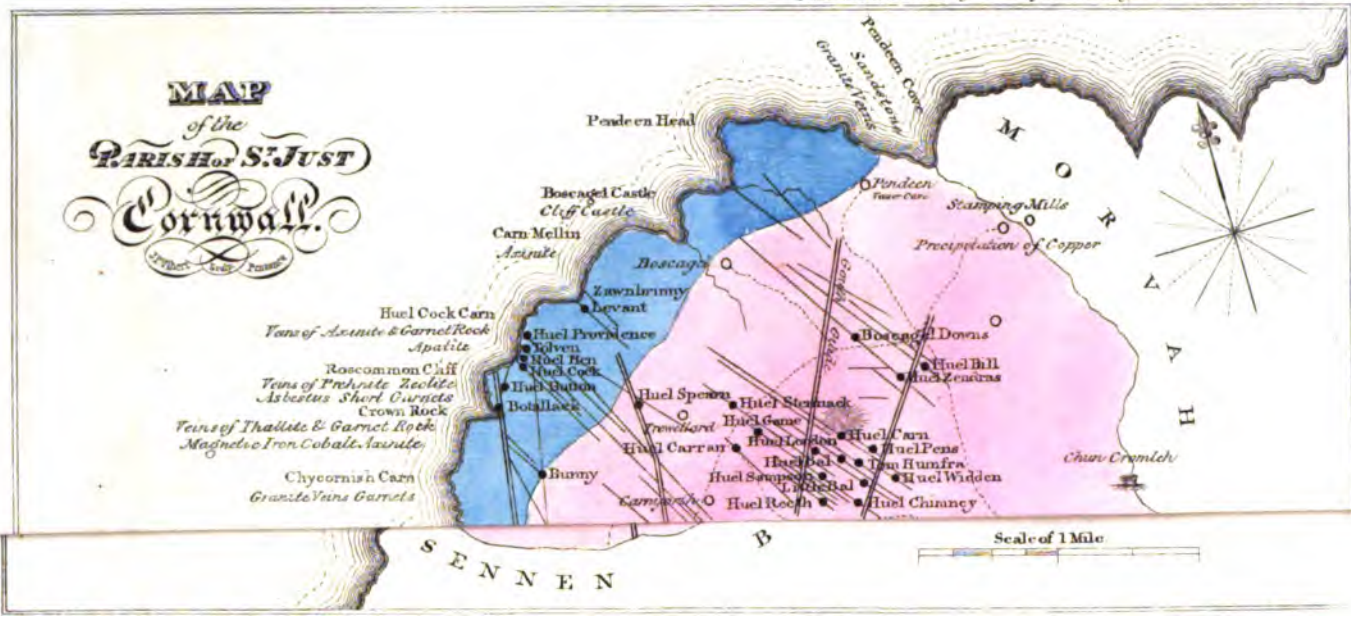
2. Yellow jasper, in which are quartz crystals so perfectly formed, as to leave no doubt of the jasper having been deposited on them; from Carnidjack.

3. Native copper, in dodecahedral crystals, from Levant.

4. Red oxide of copper, in various modifications of the octahedron, and in cubes; from Levant.

5. Carbonate of iron, in small hexahedral prisms, from a bright yellow to a dark brown colour; and also in needle crystals radiating from a centre; both from Botallack.

I perceive an omission in the description of the singular crystals of this substance, mentioned, page 298, as found in Huel Owls and Huel Bellon. It should stand as follows, "A six-sided prism, with acute "angled triangular sides, the bases of which are alternately directed "towards each extremity, where they meet, and form triangular "terminations: the sides are curved inwards at the middle, and the "edges and angles rounded."



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XVI.—*On the Knowledge and Commerce of Tin among ancient Nations.*

By the Rev. SAMUEL GREATHEED.

(Communicated in a Letter to John Dennis, Esq. Member of the Society.)

Of the commerce by which Britain has been raised to its present state of eminence, no article can vie for ancient celebrity with that of Tin. Our country was known by the name of *Cassiterides*, or the *Tin Islands*, by nations that were actually ignorant of its situation. This, indeed, was carefully secreted by its Phœnician visitors, at the same time that they exaggerated its productions. Hence ancient writers, from Herodotus to the elder Pliny, in reference to these subjects, were involved in uncertainty and error; and it has become difficult, not only to reconcile their various statements, but even to ascertain, in some instances, their meaning. Could these objects, however, be attained, there still remain facts, for which

it is not more easy to account. Metallurgy, perhaps, above every other useful art, has been remarkable, at all times, for its mysteries; and to ancient naturalists, the mysteries of *tin* seem to have been inscrutable.

No metal of equal utility is *now*, I apprehend, to be found in so few countries; and most of these were *then* unknown to the more civilized nations, and the rest were at remote distances from them. Yet Tin is named among other metals, by Moses, sixteen centuries before the Christian Era; and Homer, who wrote eight centuries later, represents it to have been used at the siege of Troy, apparently in the eleventh century before Christ. The first population of Britain will not reasonably admit of being assigned to an earlier date; and the Phœnicians seem to have first extended their navigation to the Atlantic Ocean about the same time. Another century, or more, may naturally be allowed for them to penetrate so far northward as Britain, and to obtain from its south-western extremity, and the adjacent islands, this celebrated article of their commerce. So incommunicative, however, were they, concerning the original deposit of the treasure, that Herodotus (inquisitive and indefatigable as he demonstrates himself to have been) could only learn, 400 years after Homer, that tin was procured from some western

islands, the situation of which was unknown. From that date to the Christian Era, the successive Greek writers, Aristotle, Posidonius, Polybius, Diodorus Siculus, and Strabo, manifest clearer information. They knew that Tin was obtained from the northern confines of Spain and Lusitania; and likewise from Britain, over-land through Gaul; but they mostly distinguish the latter country from the Cassiterides, without assigning the situation of those islands. Roman writers, even to a later date, discover less information, and more incredulity, on the subject. Pliny gives the name of *Plumbum candidum* to the *Cassiteron*, or Tin, of the Greeks; and scouts, as fictious, the reports that it had ever been procured from islands in the Atlantic Ocean, or any where but from Spain and Lusitania. The name of *Stannum*, together with the proper uses of Tin, he attributes to a metal which he describes as found intermixed with silver and *Plumbum nigrum* (or Lead).* With the latter metal, he represents Britain peculiarly to have abounded; but he does not intimate, that either *Stannum*, or *Plumbum candidum* (or *Album*), had ever been found there. Yet Julius Cæsar, above a century earlier, had said, *Nascitur ibi plumbum album.*† If, however, he meant *Tin*, his information was erroneous; for he represents it as

* Nat. Hist. Lib. xxxiii. Cap. 16. 17. † Bell. Gall. v. 10.

a production, not of the maritime, but the *inland* part of Britain; apparently confounding it with our interior lead mines. Of these, Pliny seems to have been better informed; the Romans having then gained possession of Derbyshire: but of British Tin, he appears to have been wholly ignorant; Cornwall being unconquered, probably, till the reign of Antoninus; and the Romans being, of all ancient polished nations, the least commercial.

The Latin term, *Stannum*, appears to have been adopted from the ancient Cornish, *Stean*, or the Welsh *Ystaen*; for which, *Plwm gwynn* (synonymous with *Plumbum album*) is sometimes used. Another term, *Alcan* (from *Can* signifying *bright*), is, however, always used for *Tin*, in the Welsh Bible; perhaps from a doubt whether *that* metal was meant. The expressions, "Thy silver is become dross,—I will purge away thy dross, and take away all thy tin,"*—accord better with the *Stannum*, than with the *Plumbum candidum*, of Pliny. The Hebrew term *Bedil*, translated Tin, likewise signifies, "that which is separated:" and the Greek translators (who every where else render it *cassiteros*, or Tin) *here* translate it metaphorically, "the wicked." That the prophet Ezekiel meant proper Tin, appears, from his enumeration of it with silver, iron, and lead, as articles of com-

* Isaiah, i. 22, 25.

merce which the Phœnicians obtained from Tarshish, or Tartessus, in Spain*: but he elsewhere describes it (with Isaiah) as if separated, by fusion, from silver; in common, however, with iron, lead, and even brass, or copper†; between the last of which, neither the Hebrews, Greeks, nor Romans, used any name of distinction; *Cuprum* being formed from *Æs Cyprium*, or Cyprian *Brass*.

Moses mentions Tin, with Gold, Silver, Brass, Iron and Lead, as part of the spoils of the Midianites‡; who had long been principal carriers of Oriental Merchandize §, and were consequently very rich in precious metals ||. Whatever, therefore, is to be understood by Tin, when first mentioned in the sacred history, it was more likely to have been procured from the East, than from the West, by the Midianites, long before Britain could probably be inhabited, or even the Phœnicians have passed into the Atlantic Ocean. The East Indies might have been peopled six or seven centuries before; and Tin, which is found abundantly at Banca, and in Siam, might have passed, by barter, through Hindostan and Persia, into the hands of the roving Midianites.

The Greeks might, in Homer's time, be supplied by the Phœnicians, with tin, from the

* Isaiah, xxvii. 12. † Isaiah, xx. 18. ‡ Numbers, xxxi. 22.
§ Genesis, xxxvii. 25, 28. || Judges, viii. 24, 26.

Spanish mines. The only use of it in the Trojan war, was that which Vulcan made to embellish the arms of Achilles; and for this he was more likely to be indebted to poetical invention, than to mercantile enterprise. When the Phœnicians, from Tartessus and Carthage, began to obtain tin from Britain, they might choose to report that *all* which they sold came from so remote and unknown a country (the course to which they laboured to conceal), rather than from any part of Spain, where other nations could more easily have penetrated. When that country was subdued, and Carthage destroyed, by the Romans, in the second century before Christ, their traffic ceased, and the Lusitanian mines fell into the power of the conquerors; but the Phocean merchants of Marseilles obtained British Tin from the depot of St. Michael's Mount; whence it was fetched in boats to the opposite coast of Gaul, carried on horses to the upper Rhone, and navigated down that river. (Diod. Sic. lib. 5. c. 9). When the Romans conquered Gaul, and invaded Britain, the natives of both countries seem to have abandoned a commerce, which could only have enriched their oppressors, and have augmented their cupidity; and it was consigned to oblivion, till the entire conquest of South Britain detected the unsuspected treasures of Cornwall.

Such appears to me to be the most natural developement of the confused, and partly contradictory accounts, which the ancients have bequeathed to us, of their knowledge and acquisition of Tin. To the Cornwall Geological Society, these brief and imperfect hints may possibly furnish matter and occasion of more satisfactory investigation.

XVII.—*On the Geology of St. Michael's Mount.*

By JOHN FORBES, M.D.

HONORARY MEMBER, AND LATE SECRETARY, OF THE SOCIETY.

(Read September, 1819.)

St. Michael's Mount is somewhat more than 200 feet high; it is said to be one mile in circumference at the base, and to contain seven acres. It is entirely composed of granite, with the exception of a patch of the slaty felspar rock, which rests on its base on the north, north-east, and partly on the north-west sides. This slaty rock is all of one bed, and is precisely of the same nature as that found at Mousehole and Newlyn. In many places it contains much mica; and has, indeed, been mistaken by some geologists for mica-slate, and by others for gneiss. It is certainly neither the one nor the other of these rocks. On the north-west side, this rock dips north, a little westerly; and on the north-east side nearly north-east: its inclination in

both places is not more than 20°. This bed of slate rises very little above the high water mark on the north-west side, but as it advances along the northern side towards the east, it gradually rises higher, and at length, at the elevation of perhaps 50 feet, constitutes part of the bold and precipitous base of the north-east front.

At its junction with the granite on the north-east and north-west sides, this rock exhibits precisely the same appearances as those described in my Paper on the Land's-end District, as occurring at Mousehole, Rosemodris, Whitesand Bay, Pendeen, Polmear, and Zennor;—viz. a confused intermixture of the two rocks,—the slate being traversed in all directions by shoots or veins of granite; and the granite, in its turn, inclosing patches of the slate. In some places there is mere apposition without intermixture of the two rocks; in others the intermixture is so complete as to render it impossible to say to which of the two, certain considerable masses belong. In some places the *kind* of intermixture is such as to be quite irreconcileable with any other theory than that of contemporaneous crystallization. In one of the specimens deposited in the Society's Cabinet, the matter composing a granite vein is seen to insinuate itself in horizontal plates, of not more than a line in thickness, between the layers of the slate.

Much has been written by Geologists on this part of the structure of St. Michael's Mount; and many differences of opinion, and even violent disputes have been maintained, as well respecting the simple matters of fact, as the attempted explanation of them. And it is true that, to eyes which have been accustomed to view nature through the medium of the artificial systems that have been invented for the purpose of explaining her operations, the phœnomena we are now considering must be esteemed as "passing strange," and well calculated to excite contradictory statements, and endless argumentation. It appears to me, however, that there is nothing more wonderful in the present objects, than in the veined configuration of the agate, or in the wavings of variegated marble; or, indeed, in any of the ten thousand instances where the same, or dissimilar minerals, simple or compound, exhibit variations in their integrant structure, or combinations and intertextures of their respective parts.

The granite of the Mount is, in general, small-grained, the felspar being of a pale white. As in all small-grained granites, the mica is the least prominent ingredient. The massive structure, on the large scale, is somewhat peculiar. The whole body of the granite is traversed by an uninterrupted series of quartz veins, which run parallel to each other with wonderful regu-

larity. They are very nearly vertical, and their direction is east and west. They are small; generally two or three inches, and never more than four or five, in width. They are distant from one another, at a medium, from six inches to a foot. On the north-east side of the Mount, many of them can be traced into the incumbent slate; an irrefragable proof of the contemporaneous formation of the two rocks; for it will scarcely admit of a doubt that these veins are contemporaneous with the granite in which they are contained.

Occasionally, though very rarely, the line of division between the vein and the rock is pretty distinct; frequently, however, there is rather an insensible gradation of the matter of the one into the other, than an obvious apposition of surfaces. The exterior parts of the veins consist of a blueish quartz, very compact, and uniformly containing a good deal of shorl. In many of the veins, indeed, the proportion of shorl is so great as to assimilate the vein-stone to the rock called shorl-rock; and in most of them this ingredient exists in sufficient quantity to give a dark colour to their external surface. This *shorlaceous* character is much more distinct towards the sides or walls of the veins, their centre being generally pure quartz, and commonly in a state of formal crystallization. In most of the veins there is a central line or

fissure, which divides them into two portions: this is formed by the close apposition and occasional union of two crystallized, or, as they may be called, *drusy* surfaces. In these fissures the quartz is found in the form of common quartz crystals, and sometimes as rock crystal. A great variety of other crystallized minerals are also found in these fissures. The most plentiful are topaz, tin-stone, and mica; but less plenteously are found apatite, wolfram, blende, &c. All these minerals are found in the same vein, and frequently in the same specimen.

The crystals of tin and of apatite are often of considerable magnitude; those of topaz are uniformly small: they are, however, extremely numerous,—many hundreds being observable on the face of some small blocks of the granite that have fallen from the precipices. The crystals of apatite are from a very light to a very dark green colour, and they exhibit most of the modifications of form which are common to that mineral. All these minerals are found in the greatest quantity in those veins of which the central fissure is wide, and the sides of the vein, adjoining the granite, are very thin.

From the vertical position and regular recurrence of these veins, the whole western front of the Mount appears as if it were composed of perpendicular strata; and this appearance is greatly encreased by the circumstance of these

veins, by their lax structure, giving great facility to the natural process of decomposition. Their structure necessarily renders them permeable to both air and water; and their verticality gives every possible facility to the action of these agents of disintegration. In consequence of these circumstances, in the greater part of the western precipice, the decay of the veinstones has left wide and deep fissures in the rock, which are seen traversing it from top to bottom, and dividing it into vertical plates or masses, many of which seem ready to mingle themselves with the mounds of similar fragments that are strewed round its base. These very obvious and striking features of degradation and decay, add greatly to the impression of sublimity and awe which the imposing mass of the Mount naturally inspires; and this feeling is, doubtless, encreased by the long hoary moss with which the surface of the rock is every where incrusted. This worn and wasted appearance of St. Michael's Mount, and the similar aspect of most of the rocks in this part of the country, has completely altered my early associations respecting the adamantine and imperishable nature of granite. Hard it indeed is, and certainly most durable, (I speak with relation to the memorials of human art,) as a material for building; yet, as seen in the sea-cliffs, and on the summits of our hills, it pre-

sents a more impressive picture of natural destruction than any other rock I have ever seen. This probably arises from the particular *manner* in which granite decays. Most other rocks, especially those of the softer kind, waste progressively, and uniformly, in every point of their exposed surface; from which it results that the mass, in every period of its progress towards destruction, still retains its original outlines and physical configuration. Granite, on the contrary, has a tendency to decompose in particular points in preference to others; and, generally speaking, these points seem to traverse it in the form of small lines intersecting each other in more or less of a rectangular direction. From this peculiarity, the mass of rocks will, in the progress of disintegration, assume the fragmented character above-mentioned. This circumstance renders the progress of decay more than usually obvious to our senses, and gives it additional force by suggesting to our imaginations the impressive associations of artificial ruins.

In dilapidated buildings, especially if large and antient, a very general feature is precisely that which is exhibited by St. Michael's Mount,—viz. a front of loose and disjointed fragments, tottering over similar fragments that have already fallen.

Much has been said respecting the relative age of different granitic rocks in different countries, and among others, respecting that of St. Michael's Mount, which has by some late writers been stated to be of that class of rocks denominated *transition* by the Wernerian School. Of the existence any where of a class of rocks entitled to this name, I have great doubt: of the impropriety of considering the granite of St. Michael's Mount as of different age and formation from that of the rest of Cornwall, I have no doubt whatever; and the appearances adduced by some writers as indicating posterior formation, are either imaginary or fallacious, or are common in other parts of the country which are considered by these very Geologists as primitive. Although the existence of strata of slate dipping *under* granite, and of beds or strata of granite *resting on*, and alternating with, slate, would not be a decisive proof, in my estimation, that one of those rocks was formed before the other; it is but justice to state that the accounts which describe such alternations as occurring at St. Michael's Mount, are totally erroneous; and I have no hesitation in saying that there is no instance to be found in the whole of the Land's-end district, where any thing like a bed of granite is found resting on slate.

I may here notice a circumstance that may tend to throw some light on the veined structure

of St. Michael's Mount,—that it shares this character with several other spots on these shores, where the main body of the granite is in contact with the slaty rocks. This is more especially remarkable at Polmear in Zennor; and in the neighbourhood of the Logan-rock. Indeed, I consider these quartz veins, and the true shorl-rock veins mentioned in a former paper, as mere varieties of the same substance.

The members of this Society are well acquainted with the various traditions and legends, of which this singular and interesting spot has been made the theatre. Of these none is more generally affirmed or credited, than that which fixes its antient and original site at the distance of some miles from the sea. And I think it extremely probable that this was really the fact. It has been found, not merely within the period of authentic record, but even within the memory of persons now living, that the sea has encroached very considerably on the level shore of this part of the bay. We indeed see it daily encroaching on the small remaining portion of flat land between Newlyn and Penzance, and between Chyandour and Marazion; and I have no doubt that before very many years are past, the low lands will be inundated, and the waters of Mount's Bay be bounded on this part of the coast, by the rocky base of the neighbouring hills. Taking into consideration, then,

the probable effect of a similar agency during a period of many centuries, with the occasional increase of its intensity from storms and tempests, it appears very likely, even independently of the weight given to the supposition by tradition, that much of what constitutes the present Mount's-bay has been, in distant ages, a low, flat, sandy valley, like the small stripe that still remains on this part of the coast. Its sheltered situation would render it favourable for the growth of trees; and, in short, I can see nothing in the nature of things in general, nor in the especial habitudes of this locality, that offers any strong grounds for doubting that our venerable and (at high water) insulated Mount, really was, what tradition so loudly declares it to have been in the days of Druidical antiquity, *The Hore Rock in the Wood.*

XVIII.—*On some instances of the alternate Disposition of the Primitive Strata which have been observed in Cornwall.*

By JOHN HAWKINS, Esq. F.R.S. &c.

HONORARY MEMBER OF THE SOCIETY.

(Read October, 1820.)

The form of this county has been in a great measure determined by a series of granite hills, (I dare not call them mountains,) which, in separate groups, run through the centre of the peninsula, and constitute the whole of its western extremity. These hills greatly out-top the surrounding country, which consists of killas or argillaceous slate, and is the principal seat of our mining riches.

The strata of killas, on their approach to the growan, overlie that rock; the lodes which run through the former being observed to descend into the latter, as they grow deeper. They reach the subjacent growan too at a shallower level, the nearer they lie to the growan hills.

If we take a general view of the primitive strata, this is not precisely that disposition of the killas with respect to the growan, which we should expect. More usually, those rocks which exhibit a very perfect crystallized aggregation are interposed, such as gneiss and micaceous slate; and a gradual transition has been traced, in many instances, from the one into the other. But in Cornwall, those members of the great series are wanting; and the killas lies immediately over the growan.

Besides the transition of the primitive strata into each other, in the order which I have here noticed, many well ascertained instances have been recorded by Werner and others, of their alternating; those of granite with gneiss, those of gneiss with micaceous slate, and those of micaceous slate with argillaceous. Even micaceous slate has been observed to alternate with granite: instances however are rare of the two extreme members of the series adopting the same relative position; and in the only instance which I consider as well ascertained, (with the exception of what follows,) the argillaceous slate is stated to have had a great admixture of mica.

Having been unable to trace satisfactorily any transition from the Cornish granite into the contiguous killas, I was by no means disposed to think there was that intimate connexion between the formation of these two rocks, which

is implied by their alternating with each other; and when, in the year 1791, I descended into the deep mine of Cook's-kitchen, and my guide Capt. Joseph Vivian pointed out to me the situations where some instances of it occurred, (for the boarding of the engine shaft prevented examination) I felt more inclined to refer the phenomenon which he spoke of, to a remarkable subsidence of the strata, which appeared to have sunk the superincumbent killas, on the hanging side of the lode, to a much lower level; than to the alternate disposition of the two rocks which the lode traverses.

There were some circumstances in the plan of this great mine, which added to my perplexity, and prevented me from following up the enquiry under ground; but as my guide, in spite of all the objections which I started, persisted in his former opinion, I thought proper to commit to writing the substance of his information, which, together with some farther particulars which were subsequently transmitted in answer to my written queries, I shall now communicate.

The growan extends to the depth of 15 fathoms from the surface, on the south side of the lode, and is incumbent on killas. The adit here is 25 fathoms below the surface.

At the depth of 13 fathoms under the level of the adit, occurs a stratum of growan, 3 fa-

thoms in breadth, on the south or hanging side of the lode; and another at the 29 fathoms level, which is still larger.

At the depth of 42 fathoms on this side, the killas ceases altogether, but on the north side it disappears at the 38th fathom; so that here there has evidently been a partial subsidence of 4 fathoms, and the legitimate inference is, that an equal subsidence must have taken place in the strata above, although the case was not so represented. Whatever may have been the defect of my information in these respects, the material point, that of the alternating disposition of the growan and the killas, seems to be sufficiently authenticated; and I confess I carried my scepticism too far in still entertaining any doubts of it. But the facts were new to me: they had not, as I thought, been well ascertained; and they threatened to subvert a preconceived hypothesis.

A circumstance of so much interest in the natural history of our Cornish strata, did not escape the notice of the late Dr. Beddoes, who had an opportunity about this time of visiting the same mine; and it is with pleasure that I record an instance of his candour. He had formed a design of presenting some account of it to the Royal Society, but on hearing the doubts which I expressed of the facts being satisfactorily ascertained, and my wish to pur-

sue the enquiry upon a future occasion, he relinquished his intention.

At the close however of the year 1792, an instance was communicated to me, in a letter from Cornwall, of similar phenomena. The merit of this discovery is due to Mr. John Tallack, an acute observer, who wanted only the advantages of education to become a Geologist. He had forwarded to me among other specimens of rocks, a pebble which exemplified the union of growan and killas. It had been found on the shore near Porthleven, "where" as he said, "the cliffs were wonderfully com-"pounded, numerous beds of growan and killas "of all dimensions, from 10 feet to an inch, al-"ternating with each other." Anxious to procure some farther information on this subject, I put some questions to him in writing; his answer to which may here be given in his own words. "As to those stratified beds of growan "and killas in Breage, near Porthleven, they lie "alternate, one above the other, in a beautiful "manner. They are not elvan, but real growan "and killas. The beds dip about 1 foot in 20 "towards the south. There are some lodes in "these cliffs, but I do not remember any slides "or heaves." All farther enquiry was suspended by my departure from England in the following summer.

We are indebted to Mr. Thomas for removing every doubt of the existence of what had appeared to me so questionable. In the explanation which he has given of his valuable map of the great mining district, he informs us that "The "mines of Dolcoath, Cook's-kitchen, Tin-croft, "Wheal Fanny, Tregajorran, and Wheal Druid, "are near the division between the granite and "the killas; but are within the killas-ground "at surface. In these mines it is observed "that strata of granite and killas appear alter-"nately overlaying each other, the divisions "between them being at various inclinations; "but sufficient information cannot be obtained "to state with accuracy the particulars: and "though the main body of granite appears to "be penetrated by the works of the mines, yet "there are not sufficient data to ascertain the "inclination of the line of its division from the "killas."—Page 10. Again, in a note annexed to the engraved view of the same district, he observes, "In some of the mines, granite and "killas are found alternately overlaying each "other, and in other places detached irregular "masses of granite are found in the killas; but "all these interspersions are near the main body "of the granite."

Such is the amount of Mr. Thomas's information. It remains for us, in order to complete the account of this very remarkable phenomenon,

situated. They are at present worked in primitive slate (the *killas* of our miners), near the junction of the slate and granite formations. The *lodes* or metalliferous veins of this district are traversed by cross-courses of clay-ironstone (as stated by Mr. Carne), which intersect both the granite and slate, and sometimes *heave the lodes* to a considerable distance.

Here I would digress for a moment to notice a very interesting discovery, accidentally made, of tin-pyrites, which has been no where found, I believe, except at Huel Rock, in St. Agnes,—Stenna-gwyn, in St. Stephens,—and Huel Scorrier, in Gwennap. I had desired a workman employed at the stamping mill and burning-house at Botherris, to send me three specimens of tin-ore containing copper, one of which I found to be an aggregation of yellow copper ore and tin-stone; another of grey copper ore and tin-stone; but the third, to my great surprize, had a compact uniform structure, perfectly homogeneous in appearance, resembling tin-pyrites in all its external characters; and on comparing it with the specimens in our cabinet, it agreed in every respect, except that its colour was a little lighter, with rather more of metallic lustre. To determine its nature with greater certainty, this substance was submitted to the following experiments. When exposed to a read heat in a covered crucible, it lost weight, and sulphur

was sublimed: calcined with free admission of air, sulphurous acid gas was evolved; it increased in bulk; changed to a dark brown colour, and lost 15 per cent in weight. In nitro-muriatic acid it readily dissolved without the application of heat, and during solution, nitric oxide gas was disengaged. Intending subsequently a more accurate analysis, a rough one was performed after the method proposed by Klaproth. The result was, in 100 parts, Copper 31, Tin 28, Iron 6, Sulphur 25, Silica with a little Alumina 7, and loss 3. The loss was probably occasioned by some of the sulphur (during the solution of the mineral in the acid) escaping in the form of sulphuric acid gas. This analysis proves beyond doubt that the mineral was tin-pyrites.

The circumstance of this specimen having occurred so readily to the workmen, induced me to suppose that tin-pyrites formed a considerable part of the ores of Botallack mine; and under that impression several experiments were made in the furnace, on the remaining portion, for the purpose of ascertaining the best method of separating the tin and copper. It is however unnecessary to detail the results, since on revisiting the mines I was unable, after diligent and repeated searches, to find even a specimen of this mineral. On questioning the workman at Botherris stamping-mill, he recollected that the pile of ore from which he took

the specimens came from that part of Botallack called Huel Hazard. Although, therefore, the idea of the tin-pyrites constituting the mass of the ore must be abandoned, it seems very probable that this mineral may be found in small quantities; for the locality is very favourable to its occurrence, the tin and copper ores being there accompanied by blende, with which tin-pyrites is usually associated.

Having ascertained that the tin and copper of the ores of Botallack and Levant mines are not united chemically, but are in mechanical combination, so intimately blended however as not to be separated by the hammer, it seemed desirable to enquire how they might be best prepared for the smelting-house, especially as the present process appeared to me susceptible of great improvement.

Before proceeding to detail the method now in use for dressing this tin-ore, it will be necessary to state briefly its nature, and that of the accompanying ores. A great variety of iron ores, particularly hæmatites, iron glance, and spathose iron ore, occur in the lodes, especially when they are in the vicinity of the cross-courses. The copper ores are principally the yellow and grey sulphurets: several others are enumerated by Mr. Carne, but they are not so abundant as to be applied to economical purposes. The tin-ore of these mines has in general the appear-

ance of compact red iron-stone, but is rather harder, owing to tin-stone being diffused throughout its substance, in very minute crystalline particles, as may be ascertained by pounding and washing the ore; and on close inspection of several fragments, small groups of acicular crystals of tin-stone might be discerned. It is also rather heavier than red iron-stone, but in every other respect it so much resembles that mineral, that a good mineralogist might be deceived: indeed, as the iron is so predominant, it should rather be regarded as such, although it contains sufficient tin to pay for its separation. On the surface, and in the interstices of this stanniferous red iron-stone, are small patches of sulphuret of copper. The lodes of Botallack and Levant contain this species of tin-ore in the vicinity of the cross-courses; but when distant from them, the red iron-stone is less abundant, and the tin and copper ores are, for the most part, disseminated in chlorite, containing also no inconsiderable portion of arsenical pyrites.

The iron-ores are rejected, as far as is possible, at the mines; and the tin and copper ores are carefully separated from each other; but sometimes they are so intimately intermixed, that much judgment is required to decide whether they can be dressed with greater advantage as tin or as copper; and indeed both these ores,

however well prepared, always contain a variable portion of each other.

The copper ore undergoes the usual processes of spalling, picking, washing, and in short the same manipulation as at other copper mines. The method of dressing the tin-ore of these mines (denominated foul tin by the miners) is much more complex. The ore is first separated at the mine, as much as possible, from the walls and matrix of the lode: it is then carried to the stamping-mill, where it is reduced to a fine powder. The water as it runs from the pit in which the pounded ore collects, is very red and turbid, owing to the iron-stone which it holds in suspension. The ore thus pulverised is washed on an inclined plane by a gentle rill of water: this operation, called buddling, has been employed from time immemorial for cleansing all kinds of tin-ore, and is admirably adapted to the purpose. The principle of the buddle is simple: the water flowing over the ore carries it, in a state of suspension, along the inclined plane; and the various substances of which the ore is composed are successively deposited on different parts of its surface, according to their several specific gravities: the earthy, with the lighter metallic minerals, (as the red iron-stone, whose specific gravity is only about 3,5) will be deposited at the bottom of the buddle; the sulphurets of copper, being about 4,5, will take their place

principally on the middle; but the tin-stone will be found at the top, as it is considerably heavier than the others, possessing a specific gravity from 6,3 to 6,9. As the whole of the ore lies on the inclined plane of the buddle, it requires much practical skill and dexterity to draw the line between the tin-ore and that which is to be rejected, In this operation some of the ore, being in a state of extreme comminution, is carried away from the buddle, suspended in water, and is collected in deep pits, by allowing the water to remain at rest: it is deposited in the form of mud or slime: hence these pits are called slime pits. The tin is obtained from this slime by a process called trunking, which is similar in principle to buddling.

The whole of the tin-ore thus obtained is, in general, less than one-tenth of the weight of the ore which passed through the stamping-mill. It is now carried to the Burning House, which is a single reverberatory furnace of the common construction, capable of holding at each charge about half a ton of ore. The calcination lasts for eighteen hours, and the temperature is kept as nearly as possible at a dull red heat, for if it should be raised much higher, the ore would melt, which is prevented by admitting air just sufficient to keep the fire burning, and also by frequent stirring with an iron rake. When the ore contains much copper, it is very apt to run

together into a mass (or in the phrase of the workmen, to *kern*): in this case it must, at the beginning of the calcination, be stirred every ten minutes, or even more frequently.

The ore thus calcined is drawn from the furnace, and exposed to the air till cold, and then put into a large tub or cask: water is poured on it, and the whole is well stirred and afterwards left at rest for a few hours, to allow the ore to settle at the bottom. The water, now become of a dark blue colour, is drawn off into another cask containing pieces of old iron, such as old hoops, shovels, horse-shoes, and the like; supported in the middle of the cask by cross bars, the rust, if any, having been first removed by hammering. The iron soon becomes coated with copper, which is rubbed off from time to time. When the water appears to have lost all its copper, which they judge of by dipping into it a piece of polished iron, it is thrown away, and its place is supplied by some more of the blue solution; but this renewal of the water depends on circumstances: if much of the ore is calcined, the water is changed as often as every second or third day: if otherwise, it is allowed to remain for many weeks. After some time the whole of the iron disappears, and copper is obtained in its place.

But to return to the calcined ore which has been washed: it is buddled over again, and the tin-ore is now found to separate readily, to a much greater extent, from the intermixed copper-ore, which by calcination has undergone a great change in its chemical constitution; and it being thereby reduced to an almost impalpable powder, is consequently carried by the water to the *tail* of the buddle, or into the slime pits. The dressing of the tin-ore is then completed by subjecting it to various processes of washing, as buddling, trunking, framing, &c. all of which are used for the preparing the tin of other mines, and are well described in Pryce's Mineralogia Cornubiensis.

The tin-ore, after having undergone all those operations, is brought to the state called *black* tin, which is carried to the Smelting House, where it is reduced to metallic or *white* tin, by mixing it with culm, and exposing it to a strong heat in a reverberatory furnace.

The most interesting circumstance in the foregoing detail, is that of the precipitation of copper by iron, which appeared to the Alchemists of old, and to the ignorant in every age, to be an actual transmutation of one metal into another; and such a delusion would have been triumphant to this day, if the light of chemical science had not expelled the darkness. This apparent transmutation can be now easily ex-

plained, as also another circumstance little less interesting,—that the copper obtained always exceeds the weight of the iron which has disappeared.

Previous to offering an explanation of the operations for dressing the tin-ore, I shall make a few observations to shew that the copper obtained by precipitation must exceed in weight the iron employed, and also to point out the relative proportion of these metals.

This precipitation of copper by iron, from water holding the former metal in solution, has been long known and employed in several countries. It appears to have been first used at the copper mines of Newsol, in Hungary, about the beginning of the last century: since that time the same process has been practised in Ireland; at the Anglesea mines in Wales, and also in many parts of this County; and, what is extraordinary, at all these places the process was accidentally discovered.

Mr. Carne, in his paper already mentioned, notices an experiment made by the Agent of Botallack, the result of which was 180lbs. of copper gained for 100lbs. of iron lost.

Capt. Grenfell informs me, that the precipitation of copper has only been in use at the Botallack and Levant mines for the last five years; and that he has lately observed the process attentively, and has found that every cwt.

of iron produces about 1 cwt. 3 qrs. of precipitate, which affords by assay 60 per cent of copper: therefore 100 lbs. of iron will give 175 of precipitate, which at 60 per cent is equal to 105 lbs. of copper.

In the Philosophical Transactions for the year 1751, there is a communication from the Rev. Henry Kenroy, stating that the waters which run from the mines on each side of the river Arklow, in the county of Wicklow, are very rich in copper, and that their value was accidentally discovered by a workman leaving his shovel in the water for some weeks, which was found so incrusted with copper, that it was thought to be transmuted into that metal; and also describing the process by which the copper was obtained from old iron. In the same communication it is also stated, that one ton of iron produced 39 cwt. of precipitate, each ton of which, when smelted, gave 16 cwt. of the purest copper, worth £10 per ton more than the copper made from the ore. In a further account of these works in the Philosophical Transactions for the year 1753, by Dr. Bond, it appears that sometimes one ton of iron was found to precipitate a ton and a half of copper.

Hence 100 parts of iron give, according to the report quoted by Mr. Carne, 180 parts of copper,

Capt. Grenfell,	105 ditto
Mr. Kenroy,	156 ditto
Dr. Bond,	150 ditto

To ascertain which of these accounts was the true one, the following experiment was made: 100 grs. of crystallized blue vitriol (persulphate of copper) were dissolved in 3 oz. of water; a clear blue solution was formed, into which two bright iron plates, weighing 265,5 grs. were immersed. In four hours the liquid acquired a darker colour with a tint of green, but in twenty four hours the blue colour had entirely disappeared, and was succeeded by a pale green: after the expiration of another day, a yellowish colour appeared on the surface of the liquid, and began to extend gradually downwards. A few drops of the liquid were then tested with ammonia, which did not indicate the presence of copper. The whole of the liquid was therefore decanted off from the iron and precipitate; the former was covered by a thick spongy coat of copper, which was readily removed, and when dried was found to have lost 22,25 grs. The precipitate, well washed and dried, weighed 25,4 grs. The yellow decanted liquid, by further exposure to the air, became much darker, till at last a brown crust formed on the surface; and after a few days fell to the bottom and was replaced by another crust: in this manner a brown precipitate equal to 15 grs was obtained.

If therefore the liquid had been left on the precipitated copper longer than was necessary it would have been gradually contaminated by

the intermixture of this brown substance; until at last it would have acquired the whole of the 15 grs. and have much diminished the value of a given quantity of the precipitate; whereas the 25,4 grs. of copper obtained, when dissolved in nitric acid, indicated but a slight trace of iron; it was therefore very pure copper. From this experiment it appears, that 100 parts of iron will precipitate 114,16 of copper, which confirms the fact that the weight of copper obtained is greater than that of the iron expended; but the difference is much less than is commonly supposed. Since even this report cannot be considered as absolutely accurate, it may be put to the test of calculation founded on the analysis of the substances employed.

Now crystallized persulphate of copper, according to Berzelius, is composed of acid 31,38: base 32,32; and water 36,30. Peroxide of copper, according to the same chemist, consists of 80 metal and 20 oxygen; and protoxide of iron of 77,6 metal, and 22,4 oxygen. Therefore as 100 parts of oxide of copper are to 80 of copper, so are 32,32 of oxide to 25,85 of copper. Hence 32,32 oxide of copper is equal to 25,85 of copper, and 6,47 of oxygen.

Again: as 22,4 of oxygen are to 76,6 of iron, so are 6,47 of oxygen to 22,41 of iron: and lastly, as 22,41 of iron are to 25,85 of copper, so are 100 of iron to 115,35 of copper. This

proportion, and that obtained by the experiment, approximate so nearly, that it may be regarded as sufficiently accurate for practical purposes.

Having adduced chemistry to confirm the observation that more copper is obtained than iron consumed, in the process of precipitation, I shall now endeavour, by the assistance of the same science, to explain the method of separating the tin and copper from the ores of Botallack and Levant mines.

The tin-ore, when put into the furnace, consists of oxide of tin, sulphuret of copper, and arsenical pyrites. During the slow calcination the sulphuret of copper loses part of its sulphur, which, uniting with the oxygen of the air, flies off in the form of sulphurous acid gas: the arsenical pyrites also loses part of its sulphur and its arsenic; whilst the tin-stone remains unaltered in chemical composition. The arsenic (in the state of vapour) and the sulphurous acid gas escape through the chimney. The calcined ore is composed of oxide of tin, sulphurets of copper and of iron, containing, however, less sulphur than previous to calcination; but in this state they are very liable to undergo change by exposure to the air: the sulphur, attracting oxygen from the air, is converted into sulphuric acid, and, at the same time, the metals become oxidated from the same source, and in this man-

ner sulphates of copper and of iron are formed. The sulphate of copper is by far the most abundant salt,* and on its account the process of precipitation is performed.

When water is poured on the calcined ore, the sulphate of copper is dissolved, forming a blue solution. The copper in this salt is at the maximum of oxidation, *that is,* in the state of a peroxide; the salt itself is therefore a persulphate of copper. When a piece of iron is immersed in this solution, a chemical change ensues, for this metal has a stronger affinity for oxygen and sulphuric acid, than copper; therefore it abstracts these substances from the salt with which it comes in contact, and the copper thus deprived is precipitated in the metallic state, covering the iron with a thin film: at this point the process terminates, or rather the explanation, for the copper is still precipitated. The iron is now covered with copper, and appears to be no longer in contact with the fluid; therefore the continuation of the decomposition can scarcely be owing to the superior affinity of the iron.

Sylvester supposed that the galvanism produced by the contact of the two metals occa-

* The sulphate of iron is generally obtained when the ore has not been sufficiently calcined, otherwise there is scarcely a trace of this substance, which, *a priori*, might be expected to be produced even to the exclusion of sulphate of copper. This is most probably owing to the iron present having been converted into peroxide of iron by calcination.

sioned the farther precipitation of the copper. Grotthus has given great plausibility to this ingenious hypothesis by the discovery of several curious facts: this explanation however is not entirely free from difficulties.

The water, after the precipitation of the copper, is green, owing to its holding in solution green vitriol, into which the expended iron is converted by its union with oxygen and sulphuric acid.

Green vitriol is a protosulphate of iron, according to Berzelius, composed of acid 28,9, base 25,7, and water 45,4. But although its oxide is at the minimum of oxidation, it will be found on referring to its composition, as already quoted, that a given quantity contains more oxygen than the peroxide of copper. Therefore according to the law established by Guy Lussac, that the quantity of acid in the metallic salt is proportional to the quantity of oxygen in the oxide, it follows that less of the protoxide of iron than of the peroxide of copper, will suffice to saturate the acid contained in the persulphate of copper; this has already been shewn to be in the proportion of 28,93 protoxide of iron, to 32,32 peroxide of copper: and that this quantity of the former oxide is capable of saturating the acid contained in 100 parts of persulphate of copper may be thus ascertained.

Protosulphate of iron, deprived of its water, is composed of acid 52,94, and oxide 47,06. Hence as 47,06 parts of protoxide of iron, are to 52,94 of acid, so are 28,93 of oxide to 32,50 of acid: now the acid in 100 parts of persulphate of copper is 31,38 according to Berzelius, and 33 according to Proust, so that the above calculation is as accurate as can be expected, when it is considered on what a number of analyses it is dependent. It is therefore perfectly concordant with the important law of Guy Lussac.

Having accounted for the consumption of less iron than the copper obtained by precipitation, I shall next proceed to consider the nature of the impurities with which the precipitated copper is contaminated, amounting in one instance to 40 per cent: part of this may be owing to some of the calcined ore being suspended in the water; this could not have been the case in the others, but it might be occasioned by the water collecting earthy substances as it flowed through the mines. This, however, can only be the source of a comparatively small part of the impurities, for by far the greatest part is a compound of iron, which is produced in the following manner. The solution of protosulphate of iron, which is formed during the precipitation of the copper, is rapidly converted into a persulphate, by absorbing oxygen from

the atmosphere; but the acid of the protosalt is not sufficient to hold in solution the oxide when brought to the maximum of oxidation; part therefore of the peroxide will remain in solution in the state of a bi-persulphate, whilst the other part, combined with only a small portion of acid, forms a sub-persulphate of iron, which, being insoluble, falls to the bottom of the water, and, mixing with the precipitate, will deteriorate its quality. If this be not interrupted, the quantity of sub-persulphate will fully amount to 40 per cent of the precipitate.

The ore after calcination is, as already stated, washed, and then returned to the buddle: the tin, not having undergone any change, is readily separated from almost the whole of the copper ore; because all the particles of the latter, by losing part of their volatile constituents, have been reduced to a fine powder, which is carried away by the stream of water, and in buddling.

Having detailed the process now in use for dressing the foul tin ore of the Botallack and Levant mines, I shall now offer a few remarks, arising from actual experiment, on this ore, by which that part relating to the precipitation of the copper may be improved. In dressing the ore all aluminous substances should be carefully separated: unless this be done, the product of the copper will be much diminished, by this

earth abstracting the acid from the persulphate of copper.

There should be a free admission of air to that part of the furnace containing the ore; for it greatly assists the separation of the sulphur, by bringing another power into action; the oxygen of the air, and the sulphur, having a strong attraction for each other, unite, and fly off in the form of sulphurous acid gas: and since it is necessary that a certain portion of sulphur be expelled to bring the ore to the state most favourable to the formation of the sulphate; this stage of the operation is of prime importance. On repeated trials, it was found that the ore exposed to heat in a covered crucible gave by precipitation only about 3 per cent of copper, whereas by calcination it afforded 5 or 6 per cent. The temperature of the ore in the furnace should never be raised above a dull red heat; and when the sulphurous acid gas ceases to be disengaged, the process should be stopt; for after this point some sulphate is formed, which would be decomposed by a red heat.

Sometimes water is poured on the calcined ore as soon as it is cold; but this is improper: the ore should be previously exposed to the air for at least a week, and be moistened from time to time, and frequently turned over with a rake. The utility of moisture, and free exposure to

air, is to facilitate the absorption of oxygen, by which the sulphuret is converted into a sulphate. This object would be best accomplished by putting the calcined ore in very shallow pits, made water tight to prevent the persulphate of copper from being washed away. The blue solution of copper should be finally received into a deep tank, furnished with a close moveable cover, and also with cross bars at different heights to support the iron.

By excluding the air as much as possible, the value of the copper will be increased, for it will contain less of the ferruginous sub-persulphate. This mode of operating may be otherwise advantageous, for after the precipitation of all the copper, the water will be a solution of protosulphate of iron, or green vitriol, which might be obtained in crystals by evaporation, in pans placed over the furnace; and notwithstanding the cheapness of this article, it would probably repay the additional expense. If the green vitriol should not be saved, the above precaution would still be desirable, for when the bi-persulphate of iron is formed, it acts on the iron used in the precipitation, and causes it to decompose the water, with the oxygen of which it unites, and the hydrogen is disengaged.

The oxide of iron thus formed abstracts a portion of acid from the bi-persulphate, and consequently a corresponding portion of sub-

persulphate will be precipitated; and if this action be not interrupted, the whole of the salt of iron in solution will be converted into a sub-persulphate.

St. Just is far from being a solitary instance in Cornwall where the tin and copper ores occur intimately blended together: I therefore trust that the above observations will not be unacceptable to a Society whose ultimate object is the application of science to the art of mining.

XX.—*On the Temperature of the Cornish Mines.*

By M. P. MOYLE, Esq.

MEMBER OF THE SOCIETY.

(Read October, 1822.)

So far back as the year 1812, my attention was drawn to the consideration of the temperature of our mines, from the circumstance of meeting with water in different levels which felt of various degrees of heat. From this time I began to collect notes of the temperature of several mines; but as they were made merely for my own gratification, without any idea of their meeting the public eye, I do not feel sufficient confidence in them to state that they are entirely free from error, as it is possible that many adventitious circumstances were disregarded, which might have affected the result. I shall, however, select only a few of my early experiments, making a distinction between them and those made within the last twelve months,

which were made with all possible care and exactness. This I have considered more particularly necessary, as the subject has become of late a matter of serious enquiry, and various opinions have been formed, as to the relative temperature of the interior strata of our earth, and its causes.

As it is only by comparing the different results of the experiments of individuals that the truth, or an approximation to it, can be elicited, I conceive too much attention cannot be paid to the mode in which those experiments are conducted. With respect to the temperatures now given, where there has been any degree of uncertainty in the result, they have been taken twice or thrice in the same spot, by different methods, such as burying the thermometer in the earth, or rock of the gallery,—in mud or water lodging in the gallery,—in the full stream of water issuing from the veins,—by allowing it to remain 15 or 20 minutes during each observation,—and by the correspondence of two or three thermometers at the same time.

I shall now detail the experiments, reserving my remarks for the conclusion.

In *Huel Unity*, the temperature in the shade at the surface was 67°. At the depth of nine fathoms in the engine shaft, the steam arising was so dense that our candles were of little use: it had the temperature of 74°, and was extremely

oppressive, which induced us to descend by another route. In a relinquished gallery 23 fathoms deep, and 10 fathoms from the engine shaft, the temperature was 54°. In another, 50 fathoms deep, a small stream of water issuing from the wall was 54½°. A working gallery at the same depth was 62°, and another was 63½°. At 150 fathoms deep, in a relinquished gallery, 20 fathoms from any working part, and free from current, the temperature was 65°; whilst in a working part contiguous to several others, at the same level, it was 74°.

Creegbraws is a copper mine on the same lode as Huel Unity; but at a considerable elevation above the latter. Many of the workings of this mine are very extensive, but most of them have been long since relinquished. A gallery 10 fathoms below the surface was 51°, the atmosphere being 43°. At 20 fathoms deep, the temperature in a relinquished gallery, 30 fathoms from any working part, was 55°. The working part at the same level was 60°. In a gallery 30 fathoms deep, the temperature in the relinquished part was 54°, and in the working part 62°.

In *Huel Trumpet* tin mine (in granite), the water drawn from the bottom and discharged at the adit was 56°. In a working gallery, 44 fathoms deep, the temperature was 58°: in a relinquished one at the same level, 54°. In a

gallery 75 fathoms deep, of which the *end* had not been worked for 18 months, the water at the extremity was 52°: in the working part of the same level, 30 fathoms distant, it was 67°. At the 86 fathoms level, remote from the working spot, the water issuing from the vein in a small but constant stream, was 53°, the working part at the same time being 68½°. The temperature of the atmosphere (it being a mild day in January 1822) was 58°.

On the 29th April 1822, I visited *Trenoweth* copper mine, situated on the same lode as Crenver and Oatfield, about 260 fathoms east of the engine of the latter. This mine has been discontinued for more than twelve months, as far as regards the presence of workmen; but the water engine is still kept at work, for the purpose of assisting the engines of Crenver. The adit is 32 fathoms deep: the water here (at the distance of 260 fathoms from the mouth of the pump by which it is drawn up) was 54°; but it gradually encreased in temperature from this place to the mouth of the pump, where it was 56°. At 47 fathoms deep, the walls of the shaft, and the water issuing from its sides, were 54°: a gallery at this level, 40 fathoms from the shaft, was 53°: the walls and floor of a gallery five fathoms deeper were 54½°. At the bottom of the mine, 66 fathoms deep, the walls of the shaft, and the water which ran through

a small crevice, were only 54°. The temperature of the surface, before our descent, was 62°:—on our return, 64°.

To shew the influence of a few (three) persons on the temperature of the air of a small mine, I found the air in the adit, on our return, 1° warmer than at our descent.

I have since ascertained the temperature of three levels which have been driven from Crenver, directly under the deepest level in Trenoweth. At the depth of 124 fathoms, it was 57°, —at 132 fathoms, 58°,—at 142 fathoms, 58°. Five months before, when the miners were at work in the last-mentioned level, the temperature was 68°. To what then must we attribute that superiority of temperature?

In *Oatfield* copper mine, in May 1822, the temperature in the engine shaft, at the adit level, was 61°. At the depth of 182 fathoms, it was 77°, and at 212 fathoms deep, and 80 fathoms east of the shaft, 78°. At 222 fathoms deep, and 100 fathoms east of the shaft, it was 81°; but at the same level, 60 fathoms west of the shaft, it was only 78°: neither of these spots were working places, but the latter was more contiguous to them than the others. At the depth of 232 fathoms, in a working part, 12 fathoms east of the shaft, it was 80°; and only 4 fathoms deeper, 30 fathoms west of the shaft, in a confined *end*, it was 85°. Here the water

issuing from two small veins, a few feet apart, indicated the different temperatures of 82° and 86½°.

Since the temperature of the different parts of this mine has been taken, the pumps have been drawn up from the deepest part, and the shaft, below the depth of 182 fathoms, has been for some months full of water. At this level the temperature was previously 77°; but a few months afterward, when the water had risen to the level, its temperature, a few feet below its surface, was 69°; and at the depth of 12 feet in the water, it was 71°. A fortnight after this I repeated the experiment, and found the temperature, a few feet below the level, 66°; and at 12 feet deep in the water, 67°. This shews that the water is gradually cooling, and becoming of the temperature of the surrounding earthy strata, it having cooled 3° in a fortnight, and 11° since its admission into the shaft.

In another part of this mine, 150 fathoms south of the former, the water at 40 fathoms deep, in a relinquished gallery, was 56°; but in the same level, at a considerable distance, where the men were at work, it was 61°. At 50 fathoms deep it was, in a relinquished spot, 56°; and in a working spot at some distance 58°. At the depth of 70 fathoms the floor of a working gallery was only 60°; and the water issuing from the vein only 56°.

In *Crenver* copper mine, very little work has been done for a great while. At 50 fathoms deep, and 50 fathoms east of the engine shaft, the temperature was 55°;—at 72 fathoms deep, 56°;—at 82 fathoms, 61°;—at 102 fathoms, 62°; —at 112 fathoms, 64°;—at 122 fathoms, 64° in the shaft; but in a gallery 60 fathoms east, only 60°;—at 132 fathoms, 63° in the shaft; but 200 fathoms east of it, only 61°;—at 142 fathoms, 62°; but at 30 fathoms west, it was 64°, and at 200 fathoms east (the only part of the mine which was at work) it was 68°.

Huel Abraham is on the same lode as Trenoweth, Crenver, and Oatfield, and is, in almost every part, in full work. At 222 fathoms below the surface, the temperature was 84°. At 232 fathoms deep, at the extremity of the level, on a Monday morning, before the workmen had returned to labour, and where a machine was erected for blowing fresh air to the miners, the thermometer stood at 90°; but a few days afterwards, when a communication had been opened, it fell to 86°. At the depth of 242 fathoms, it was, in one gallery, 84°, and in another (the only spot where there were no workmen) it was 86°.

I shall now mention the result of some experiments to ascertain the temperature of the water, at different depths, in mines which have been long abandoned.

In *Trevenen* tin mine I found the temperature of the water in the adit, 14 fathoms below the surface, 52°, whilst that of the atmosphere was 56°. In one of the shafts, which reached to the lowest part of the mine, and from which the water continually overflowed, it was 52½°.

Herland copper mine, in Gwinear, has ceased working (except above the adit) 15 years. On the 28th May 1822, while the temperature in the shade at the surface was 64°, and in the sun 74°, I found that of the water running through the adit, 32 fathoms deep, 52°; as we approached the engine shaft, it was encreased to 53°; and on sinking two self-registering thermometers, properly secured in a box, with iron weights, the temperature, at the depths of 10, 20, 40 and 60 fathoms in the water, was uniformly 54°. In another shaft in this mine, 60 fathoms north-west of the former, the water running through the adit was 54°, and at 10, 20, and 40 fathoms deep, 56°.

On the 8th of June 1822 I visited *Huel Pool* and *Huel Rose* lead mines near Helston. In the former the temperature of the water, at 10 and at 20 fathoms deep, was 53°. In another shaft it was precisely the same.

In Huel Rose, the water in the engine shaft was, at ten fathoms deep, 53½°,—at 20 fathoms, 53½°,—at 40 fathoms 53¼°,—and at 54 fathoms, (the greatest depth to which I could drop the

thermometer) only 53°. The time allowed for the thermometer to remain at the different depths (except the last) was ten minutes, which perhaps was scarcely long enough.

In *Huel Alfred* (visited in July 1822) the temperature of the water in the adit, 18 fathoms below the surface, was 56°; and at the several depths of 10, 26, 40, 60, 100, and 112 fathoms below the adit, it was uniformly the same.

Relistian mine, in Gwinear, (visited on the same day,) is reported to have been, when at work, much hotter than mines in general; but I found the water in the adit, 25 fathoms deep, only 55°; and at 10, 20, and 25 fathoms below the adit, it was still the same.

In making a few observations on the foregoing experiments, I must remark, in the first place, that in mines which are at work, scarcely two places of equal depth below the surface, and under similar circumstances, exhibit the same temperature; nor can I find, where it encreases with the depth, that there is any certain ratio; it being often, as in Oatfield, colder at 70, than at 40 fathoms deep. As these differences and irregularities of temperature always occur in mines which are at work, they must arise from adventitious causes. I am therefore of opinion that the true temperature of any part of a mine in the full course of working, is

difficult of attainment, and that we must have recourse to those mines, and parts of mines, which have been long since quitted by the miner, in order to obtain any thing like a true datum.

Most of the deep mines now at work shew an increase of temperature of more than 1° for every 10 fathoms of descent; at least it amounts to this on the whole, although its progressive ratio is not in that proportion: to shew therefore that this increase of heat arises from causes operating only in mines at work, we have merely to refer to the temperature of mines long since relinquished, the highest of which appears to be 56°; only 3° above the mean of this neighbourhood.

The experiments already mentioned clearly prove that the water in relinquished mines exhibits nearly the same degree of temperature at all depths, and as it is demonstrated that water is a bad conductor of caloric, except in an upward direction, it is natural to infer that the temperature of the deepest parts of those mines which are full of water, may be ascertained by sinking the thermometer a few feet, or fathoms, below the surface.

The water in the two shafts of Herland mine indicated different temperatures, viz. 54° and 56°; and this difference was the same at all depths. Now had the temperature of the earth

been uniform at the same depth, there would have been no difference whatever.

The temperature of the water at the deepest part of Huel Alfred (130 fathoms), was only 56°; but according to the theory of progressive heat, it ought to have been 66°.

The hot springs which frequently occur, whilst they prove the existence of causes sufficient to give them their high degree of temperature, prove at the same time, by their rarity, the local and adventitious nature of those causes. Such springs are sometimes met with at the very bottom of our mines, as at Dolcoath.

The water issuing immediately from copper veins is generally warmer than that which flows from those of tin. May not this arise from the action of oxides of iron and sulphuretted pyrites, which are more abundantly found in copper than in tin lodes?

I need not here enumerate the many adventitious causes of heat in mines; but from the whole of my experiments I cannot but conclude that the doctrine of the progressive increase of heat in proportion to the depth, is without foundation, since it has been proved that it may be as cold at the depth of 100 fathoms, as the mean of this climate, which could not be the case were the progressive theory correct.

Were we to admit, for a moment, the increase of heat from the surface to the centre of the

earth, at the rate of about 1° for every ten fathoms, what would be the result? Commencing at 53°, the annual mean of our climate, we should, at the depth of 264,000 fathoms, or 300 miles, arrive at that degree of heat which we suppose capable of melting, and of retaining in a state of fusion, every ingredient of which this globe is composed; for as far as our knowledge extends, I believe 25,127° is the greatest heat which has yet been observed. What then must be the heat existing at the centre of the earth? At the same ratio, it would amount to 366,608°: a heat so far beyond what we have any instrument capable of measuring, that our senses become bewildered at its contemplation. In this case there must be a mass of melted matter existing at the centre, equal to 7,733 miles in diameter, taking the circumference of the earth at 25,000 miles.

We have, however, no facts to warrant such a conclusion, nor indeed, in my opinion, any other conclusion than that it may be as cold at the very centre of the earth, as at any depth below the surface.

XXI.—*On the Serpentine District of Cornwall.*

By the Rev. JOHN ROGERS,

MEMBER OF THE SOCIETY.

(Read October, 1822.)

The great serpentine district of Cornwall, extending from Porthalla on the north-east coast to Mullion on the north-west, has been carefully examined by two intelligent Geologists, in whose papers is comprised most of the information respecting the geology of this district, which has been laid before the public: but an accurate knowledge of a district of so complex a character can only be attained by repeated examination.

The following remarks were made during some late excursions to the coasts of St. Keverne and Ruan Minor, and are chiefly confined to some particulars which have not been remarked either by Mr. Majendie or by Professor Sedgwick.

It is well known that greywacke and clay-slate alternate on Mawnan Glebe. On the opposite side of Helford river, the conglomerate mentioned by Mr. Majendie * may be seen passing into greywacke, between the Nare and Carnmere; and Carnmere headland consists entirely of conglomerate. The same compound rock occurs again in the cliffs at Turval, a quarter of a mile north of Porthalla. Near the same place, loosely cemented iron-sand, approaching to conglomerate, and containing pebbles of clay-slate, quartz, felspar, and greenstone, rests on the clay-slate, and sometimes fills the fissures. The dip of the clay-slate is from south to south-east. In a small rocky bay, 200 yards north of Porthalla, I found, at low water, several large blocks of grey limestone with veins of white calcareous spar: they were rounded by attrition and eroded by the workings of shell-fish: the largest is full 15 feet long; the next in size, 10 feet by 4. On some blocks I observed a junction with clay-slate; and in the clay-slate of the adjoining cliffs I saw veins of calcareous spar. The dip of the clay-slate is south-east at an angle of $35_{\circ}$. It is a matter of no small difficulty to account for the appearance of these immense masses of limestone in such a situation. From their size we must necessarily look for their origin in the immediate neighbourhood;

* Vol. I. p. 36.

but I am not aware that any limestone has been found within many miles of the spot; nor does it resemble any Cornish limestone that I have seen.

About 200 yards south of Porthalla, serpentine first makes its appearance, just beyond a mass of crumbling clay-slate. The reddish talc of Porthalla rests, as Mr. Majendie observes, on clay-slate; but between the talc and the serpentine a mass of rock intervenes, near the beach, which I think is a coarse-grained hornstone, sometimes approaching in appearance to the porphyry of Kennick Cove. Between Porthalla and Pentire Point, which is the nearest headland south of Porthalla, and immediately north of Dranna, serpentine occurs in at least four places, alternating with greenstone. This should be seen above the cliff. I observed, as Professor Sedgwick remarks, greenstone resting on serpentine, and also serpentine resting on greenstone, which is the most usual order of superposition: indeed, where alternations take place at an inclined angle, it is evident that each rock will sometimes appear above the other. About a quarter of a mile north-west of Pentire Point, greenstone and serpentine, with their respective characters distinctly marked, may be seen near the sea, alternating in beds from two to six inches thick, with thin layers of talc interposed, and dipping west. I

could find no serpentine from Pentire Point to Porthoustock; though the greenstone has in some places, externally, the appearance and glossy steatitic faces of serpentine; but may be distinguished by its lying in beds dipping from north to north-west, and by its more compact and uniform texture.

A little beyond Porthkerris Cove, and above Pednerris Point (the headland immediately north of Porthoustock), I found beds of what appears to be whitish semi-transparent hornstone passing into quartz, interposed between the greenstone, and conformable to it. Hornstone frequently accompanies greenstone. The hornblende formation of St. Clere is almost encircled by hornstone, though differing much in its appearance from that of Pednerris.

I landed on one of the Manacle rocks, and found it composed of fine syenite, consisting of violet felspar, diallage, and common hornblende, and traversed by nearly vertical veins of greenstone, from 15 inches to 5 feet wide, and dipping east. In the middle of some of the veins are small veins of saussurite running parallel with the greenstone.

At Coverack the prevailing rock is serpentine, which extends as far as the mill, a quarter of a mile north of the village. Towards the north of the Cove it abounds with fine diallage, and is sometimes intermixed with white saussurite:

nearly vertical veins of diallage rock, consisting chiefly of diallage metalloide and saussurite, pass through it in different directions. Syenite of various kinds appears in veins and irregular masses. Immediately under Sanders's Inn, within the pier, serpentine rests on a beautiful rock, consisting of white, pink, and green saussurite, and violet felspar: the serpentine dips west at an angle of 30°. Here also veins of diallage rock, from 2 to 18 inches wide, and nearly vertical, traverse the serpentine in various directions: the serpentine again appears a short distance towards the east. The diallage is sometimes distinctly crystallized in six-sided tables.

I did not examine the coast from Coverack to Pedn-boar point; but as far as I could judge from the character of the rocks as seen from the sea, the whole appeared to be serpentine, as laid down in Mr. Majendie's map.

There is not a more interesting spot for geological observations in the whole district than Kennick or Kenmark Cove, a low sandy cove near Gwendra. The alternations of greenstone, porphyry, and serpentine, mentioned by Professor Sedgwick, may be distinctly traced from the beach to the top of the cliff. The dip and angle of the line of junction are nearly the same, viz. north-east, at an angle of from 45° to 60°. The porphyry and greenstone mentioned by Pro-

fessor Sedgwick, constitute a mass of large irregular veins or beds, confusedly aggregated. The porphyry exactly resembles that of Kynance Cove, which, though called granite by Sir Humphry Davy,* is, I think, more correctly described by Mr. Majendie and Professor Sedgwick, as porphyry. The serpentine is dark green, beautifully spangled with diallage, and of rather a friable texture. Veins of common and wood-like asbestus, steatite, and calcareous spar, intersect the serpentine and fill the lines of junction. In one vein I found talc crystallized in six-sided tables, like that of Stenna-gwyn mine.

On the beach I found massive green diallage, red jasper, and flints, apparently from a chalk formation. At a copper mine called Dowlas, near Kennick Cove, double refracting calcareous spar has been found; and I observed a vein of limestone and calcareous spar at Perran-vose.

The Frying-pan, a little to the south-west of Cadgewith, is evidently formed, as stated by Professor Sedgwick, by a decomposing bed of serpentine. The entrance from the sea is through a large natural arch of serpentine into an amphitheatre open to the action of the sea, and formed by the successive fall and destruction of masses of serpentine, intersected by soft veins of talc and steatite: a small stream which trickles over the serpentine facilitates its disin-

* Vol. I. p. 46.

tegration. On the north-east side of the amphitheatre a bed of serpentine is seen resting on a gibbous bed of greenstone.*

Opposite the arch, the greenstone rises to the top of the cliff, and at the south-west side the greenstone and serpentine are so blended that it is almost impossible to define their limits. The dip of the greenstone forming the cliff a little south-west of the Frying-pan, is a little west of north.

I will conclude with a few general observations on this interesting geological district.

The clay-slate of this southern peninsula of Cornwall evidently rests on the central formation of granite.† The dip is generally south-east. This is the dip on both sides of the Helford river, at Gweek, at the Nare, at Porthalla, at Mullion, &c. The general dip of the greenstone is north-west; and it may be said almost always to vary from north to west in this district. It dips north-west the whole way from Porthalla to Porthoustock; and north by west near the Frying-pan, and near Penvose Bay, below Landewednack Church. Mr. Majendie describes the greenstone from Cadgewith to the Lizard as dipping north. The rocks of this district may be divided into four classes: 1st. Clay-slate, which forms a semicircular boun-

* See Mr. Majendie's Paper, vol. I. p. 36.

† Idem, p. 36.

dary from the north-east to the north-west.* 2nd. Greenstone (sometimes passing into hornblende-slate), which appears in patches on the west, the south, and the east, and I think also on the north-west, near Bonython, and certainly near the road leading from Trelowarren to St. Martins. The great variety of beautiful rocks which chiefly occur from Porthoustock to Coverack may be comprized under the general name of syenite. They consist chiefly of hornblende or schiller-spar, the diallage of Hauy; and felspar, either crystallized or compact. The diallage rock of Mr. Majendie consists generally of large crystals of diallage metalloide imbedded in saussurite, sometimes with red spots resembling serpentine, and sometimes with violet felspar. This I think cannot be geologically distinguished from the porphyritic syenite. The 4th rock of this district is serpentine, extending north and south from Trelowarren entrance gate to Landewednack, and from the neighbourhood of Kennick Cove on the east to Mullion on the west.

* See Mr. Majendie's Map in vol. 1.

An Account of Tin raised in Cornwall, in the year 1817.

		Blocks of Common Tin.	Blocks of Grain Tin.
Lady-day Quarter,	- - - - -	5198	795
Midsummer Quarter,	- - - - -	5892	889
Michaelmas Quarter,	- - - - -	5739	965
Christmas Quarter,	- - - - -	5157	744
		21,986	3393

Total, 25,379 Blocks, or 4120 Tons.

This quantity is larger than was ever before produced in a single year, as far as is known.

An Account of Tin raised in Cornwall, in the year 1818.

		Blocks Common.	Blocks Grain.
Lady-day Quarter,	- - - - -	4794	1023
Midsummer Quarter,	- - - - -	5092	1082
Michaelmas Quarter,	- - - - -	4398	690
Christmas Quarter,	- - - - -	4989	980
		19,273	3775

Total, 23,048 Blocks, or 3745 Tons.

An Account of Tin raised in Cornwall, in the year 1819.

		Blocks Common.	Blocks Grain.
Lady-day Quarter,	- - - - -	4548	710
Midsummer Quarter,	- - - - -	5041	526
Michaelmas Quarter,	- - - - -	4149	370
Christmas Quarter,	- - - - -	3287	250
		17,025	1856

Total, 18,881 Blocks, or 3068 Tons.

An Account of Tin raised in Cornwall, in the year 1820.

		Blocks Common.	Blocks Grain.
Lady-day Quarter,	- - - - -	3651	516
Midsummer Quarter,	- - - - -	4204	615
Michaelmas Quarter,	- - - - -	3793	484
Christmas Quarter,	- - - - -	3690	131
		15,338	1746

Total, 17,084 Blocks, or 2775 Tons.

An Account of Tin raised in Cornwall, in the year 1821.

		Blocks Common.	Blocks Grain.
Lady-day Quarter,	- - - - -	3919	486
Midsummer Quarter,	- - - - -	4771	554
Michaelmas Quarter,	- - - - -	4002	582
Christmas Quarter,	- - - - -	4330	629
		17,022	2251

Total, 19,273 Blocks, or 3132 Tons.

An Account of the Annual Produce of the Tin Mines of Cornwall, from the Year 1750 *to* 1821 *inclusive.*

Year.	Blocks.	Tons.	Year.	Blocks.	Tons.
1750	18,698	2876	1775	17,024	2619
1	14,776	2273	6	17,240	2652
2	16,574	2550	7	18,010	2770
3	16,358	2516	8	16,302	2515
4	17,708	2724	9	17,411	2678
5	17,924	2757	1780	19,022	2926
6	18,033	2774	1	16,969	2610
7	17,887	2752	2	16,548	2546
8	17,681	2720	3	16,705	2570
9	17,140	2637	4	17,456	2685
1760	17,662	2717	5	18,753	2885
1	15,571	2395	6	22,096	3399
2	16,801	2584	7	20,824	3204
3	17,786	2736	8	21,790	3352
4	16,997	2618	9	22,132	3405
5	17,923	2757	1790	20,753	3193
6	19,861	3055	1	22,561	3470
7	18,529	2850	2	24,763	3809
8	17,334	2667	3	20,805	3202
9	18,838	2898	4	21,793	3351
1770	19,355	2977	5	22,353	3440
1	18,349	2823	6	19,902	3061
2	20,531	3159	7	21,063	3240
3	18,540	2852	8	18,332	2820
4	15,975	2458	9	18,603	2862

Year.	Blocks.	Tons.	Year.	Blocks.	Tons.
1800	16,397	2522	1811	14,675	2384
1	14,552	2328	2	14,606	2373
2	16,420	2627	3	14,306	2324
3	18,212	2914	4	16,069	2611
4	18,716	2993	5	18,101	2941
5	17,139	2742	6	20,608	3348
6	17,846	2855	7	25,379	4120
7	15,168	2426	8	23,048	3745
8	14,589	2330	9	18,881	3068
9	15,680	2508	1820	17,084	2775
1810	12,528	2006	1821	19,273	3132

An Account of the Produce of the Copper Mines of Cornwall, in Ore, Copper, and Money, in the Year ending the 30th June, 1818.

N. B. Fractional parts of a Ton of Copper, and a Pound Sterling, are omitted.

	Tons of Ore.	Tons of Copper.	£
United Mines	11,506	989	88,541
Dolcoath	10,076	758	65,722
Huel Abraham, &c.	9,620	714	60,640
Treskirby	4,634	414	37,894
Huel Unity & Poldice	4,989	410	35,233
Crennis	3,851	366	31,245
Huel Squire	2,786	258	23,301
Chacewater	3,772	253	21,321
Pembroke	2,558	213	18,101
Huel Neptune	1,453	175	15,051
Huel Music	800	165	15,814
Huel Damsel	1,860	159	13,988
Huel Basset	17,33	157	14,075
Camborn-vean	1,247	134	12,703
Huel Fanny	1,362	119	10,911
Huel Regent	1,105	116	10,085
Tingtang	1,279	108	9,785
Huel Friendship	1,565	97	7,402
Huel Gorland	1,370	92	8,307
Huel Chance	749	90	8,294
Huel Treasure	1,202	89	7,413

	Tons of Ore.	Tons of Copper.	£
Tincroft	1,394	86	7,331
Gunnis-lake	889	74	5,745
Trenoweth	1,163	69	5,430
West Huel Squire	548	64	5,898
Cook's Kitchen	769	59	5,416
Huel Clowance	441	43	4,130
Huel Alfred	860	41	3,248
Cuddra	491	36	2,980
Consolidated Mines	429	32	2,975
Botallack	225	29	2,565
Creegbraws	333	23	2,037
Weeth	206	22	2,205
North-downs	214	19	1,697
Huel Sparnon	178	15	1,429
Tregajorran	116	12	1,043
Huel Jewel	158	12	1,043
Lambo	150	12	1,120
West Huel Fortune	188	12	1,076
Huel Spinster	151	11	978
Tresavean	187	11	872
Godolphin	127	10	1,015
Mines under 10 tons	659	48	4,128
Private contracts	1,132	98	7,790
	80,505	6714	587,977

Average Standard, £121 per Ton.

An Account of the Produce of the Copper Mines of Cornwall, in Ore, Copper, and Money, in the Year ending the 30th June, 1819.

	Tons of Ore.	Tons of Copper.	£
United Mines	10,039	846	85,074
Dolcoath	11,256	828	85,428
Huel Abraham, &c.	11,073	797	79,457
Treskirby	5,062	442	44,714
Huel Squire	4,706	412	41,915
Huel Unity & Poldice	4,937	360	37,768
Crennis	4,529	353	34,247
Chacewater	4,696	247	23,167
Pembroke	2,872	209	19,763
Huel Music	1,040	176	18,979
Tincroft	3,238	151	14,074
Huel Damsel	1,749	145	14,237
Huel Neptune	1,428	141	15,112
Huel Gorland	1,685	130	13,059
Tresavean	1,316	114	11,259
Camborn-vean	1,071	113	12,341
Huel Basset	1,174	113	12,023
Cook's Kitchen	1,527	111	11,537
Huel Clowance	1,478	108	10,865
Huel Chance	1,035	102	10,165
West Huel Squire	849	99	10,558
Weeth	883	89	9,846

	Tons of Ore.	Tons of Copper.	£
Huel Regent	926	84	8,289
Tingtang	981	78	7,646
Lambo	859	76	8,329
Huel Fanny	940	75	8,247
Cuddra	1,306	74	6,602
Consolidated Mines	774	72	7,259
Penberthy Crofts	773	52	5,110
Huel Friendship	794	40	3,789
North Roskear	663	40	4,087
Trenoweth	850	38	3,394
Huel Alfred	978	36	2,993
Botallack	262	35	3,808
North-downs	382	32	3,267
Huel Treasure	512	31	3,038
South Towan	289	22	2,275
Huel Sparnon	317	21	2,164
Creegbraws	329	20	1,866
West Huel Fortune	284	15	1,408
Tregajorran	113	12	1,279
Condurrow	146	10	1,060
Mines under 10 tons	1,213	88	8,533
Private contracts	1,900	177	18,000
	93,234	7214	728,032

Average Standard, £136 per Ton.

An Account of the Produce of the Copper Mines of Cornwall, in Ore, Copper, and Money, in the Year ending the 30th June, 1820.

	Tons of Ore.	Tons of Copper.	£
United Mines	11,615	994	83,131
Dolcoath	10,743	782	66,723
Huel Abraham, &c.	10,953	759	61,312
Treskirby	4,376	408	34,622
Huel Squire	3,468	314	26,887
Huel Unity & Poldice	3,566	274	23,632
Chacewater	4,103	226	17,965
Tresavean	2,879	224	18,812
Pembroke	2,701	193	15,487
Penberthy-crofts	2,545	179	14,476
Huel Damsel	1,838	166	14,266
Cook's Kitchen	2,120	161	13,702
Huel Basset	1,397	148	13,091
West Huel Squire	1,148	139	13,085
Huel Gorland	1,604	135	11,493
Huel Clowance	1,687	116	9,656
Huel Chance	1,114	115	9,850
Huel Neptune	1,168	108	9,515
Weeth	929	105	9,444
Tincroft	1,862	104	8,655
Tingtang	1,139	103	8,652
Consolidated Mines	1,171	98	8,265

	Tons of Ore.	Tons of Copper.	£
Lambo, &c.	1,080	97	8,288
Camborn-vean	868	92	8,438
Crennis	969	84	7,601
Huel Music	572	79	7,003
Binner-downs	816	70	5,749
Huel Harmony	691	69	5,989
Huel Fanny	768	66	5,884
Cuddra	1,080	62	4,879
Botallack	456	59	5,028
Huel Buller	405	45	3,798
North-downs	477	45	3,808
North Roskear	587	37	3,039
Creegbraws	505	32	2,489
Huel Speedwell	343	26	2,007
Huel Alfred	758	26	1,706
Huel Regent	230	25	2,436
Trenoweth	529	21	1,430
Huel Charlotte	222	20	1,590
Huel Treasure	321	18	1,428
South Towan	212	18	1,486
Huel Friendship	351	17	1,374
Barncoose	112	16	1,423
Huel Sparnon	154	13	1,161
Mines under 10 tons	2,040	138	10,992
Private contracts	4,000	338	28,600
	92,672	7364	620,347

Average Standard, £119 per Ton.

An Account of the Produce of the Copper Mines of Cornwall, in Ore, Copper, and Money, in the Year ending the 30th June, 1821.

	Tons of Ore.	Tons of Copper.	£
United Mines	9,793	876	68,297
Dolcoath	11,344	808	62,259
Huel Abraham, &c.	9,591	719	54,353
Treskirby	4,696	467	36,789
Pembroke	4,310	337	25,460
Huel Drewlas	3,349	330	26,549
Consolidated Mines	3,402	282	21,286
Huel Unity & Poldice	3,056	252	19,668
Chacewater	3,889	216	15,892
Huel Squire	2,329	197	15,208
Penberthy-crofts	2,543	191	14,442
Cook's Kitchen	22,60	165	12,549
Tingtang	1,604	163	12,931
Tresavean	2,197	159	11,827
Crennis	1,816	158	11,620
East Crennis	1,448	151	11,357
Huel Damsel	1,533	142	11,150
Camborn-vean	1,236	141	11,668
Huel Basset	1,127	134	10,836
Huel Chance	1,263	128	10,150
Huel Gorland	1,377	117	9,228
Huel Speedwell	1,516	115	9,368
Binner-downs	1,386	114	8,881
Huel Harmony	1,093	106	8,478

	Tons of Ore.	Tons of Copper.	£
Huel Charlotte	872	87	6,762
Huel Treasure	766	84	6,335
Tincroft	1,384	84	6,394
Weeth	630	76	6,386
Huel Neptune	776	73	5,835
West Huel Squire	580	61	5,071
Botallack	445	60	4,938
North-downs	546	58	4,637
Cuddra	1,168	53	3,496
Huel Fanny	508	50	4,024
Huel Maid, &c.	607	47	3,443
Huel Music	346	47	3,844
Trelissick	756	45	3,296
Huel Buller	502	45	3,495
South Towan	479	43	3,378
Huel Fortune	471	40	3,087
North Roskear	650	40	3,014
Lanescot	331	32	2,489
Huel Rock	445	31	2,243
Huel Spinster	303	27	2,127
Creegbraws	369	26	1,988
Great Hewas	440	24	1,602
West Mulfra	151	23	1,814
Huel Alfred	510	17	935
Charlestown	222	15	1,111
Unanimity	251	12	774
Mines under 10 tons	1,337	102	6,868
Private contracts	4,800	393	29,200
	98,803	8163	628,832

Average Standard, £111 per Ton.

An Account of the Produce of the Copper Mines of Cornwall, in Ore, Copper, and Money, in the Year ending the 30th June, 1822.

	Tons of Ore.	Tons of Copper.	£
Consolidated Mines	12,861	1114	80,311
United Mines	8,533	800	58,279
Dolcoath	10,703	748	53,890
Huel Abraham, &c.	8,834	644	45,408
Pembroke	5,294	441	31,288
Treskirby	4,251	436	32,772
East Crennis	2,865	346	25,183
Poldice and Huel Unity	3,324	301	22,057
Huel Charlotte	2,131	276	21,075
Huel Treasure	2,844	270	18,263
Lanescot	2,399	235	16,793
Tingtang	2,380	231	17,292
Huel Harmony	2,068	210	15,900
South Huel Buller, &c.	2,177	209	15,675
Chacewater	2,964	178	12,195
Huel Squire	1,895	167	12,270
Huel Speedwell	1,869	152	11,060
Huel Damsel	1,235	139	10,414
Huel Gorland	1,323	134	10,149
Tresavean	2,174	134	8,949
Crennis	1,550	132	9,183
Huel Chance	1,199	127	9,436
Huel Neptune	1,064	122	9,447
Binner-downs	1,329	118	8,520

	Tons of Ore.	Tons of Copper,	£
Huel Clowance	1,461	118	8,804
Penberthy-crofts	1,520	112	7,799
Cook's Kitchen	1,664	110	7,837
Huel Basset	861	106	7,987
Camborn-vean	880	94	7,144
Huel Drewlas	921	86	6,299
South Towan	1,027	80	5,829
Huel Maid, &c.	821	71	5,177
Huel Spinster	702	65	4,848
North Roskear	933	64	4,803
North-downs	583	60	4,503
Trelissick	883	50	3,305
Botallack	456	47	3,327
Huel Vor	301	42	3,285
Huel Music	328	39	2,929
Tregajorran	210	36	2,826
West Mulfra	235	33	2,340
Levant	293	31	2,178
Tincroft	512	30	2,056
Huel Fanny	233	19	1,351
St. George	185	19	1,351
Huel Rock	282	19	1,152
Huel Pink	139	15	1,152
West Huel Squire	155	13	962
Huel Alfred	312	12	738
Creegbraws	130	10	749
Mines under 10 tons	1,230	95	6,545
Private contracts	2,230	191	13,200
	106,723	9331	676,285

Average Standard, £104 per Ton.

An Account of the Annual Produce of the Copper Mines of Cornwall, from the Year 1771 *to* 1822 *inclusive.*

Years.	Tons of Ore.	Tons of Copper.	£	Standard.*
1771	27,896	3,347	189,609	81
2	27,965	3,356	189,505	81
3	27,663	3,320	148,431	70
4	30,254	3,630	162,000	68
5	29,966	3,596	192,000	78
6	29,433	3,532	191,590	79
7	28,216	3,386	177,000	77
8	24,706	2,965	140,536	72
9	31,115	3,734	180,906	73
1780	24,433	2,932	171,231	83
1	28,749	3,450	178,789	77
2	28,122	3,375	152,434	70
3	35,799	4,296	219,937	76
4	36,601	4,392	209,132	72
5	36,959	4,434	205,451	71
6	39,895	4,787	237,237	75
7†	38,047	- - -	190,738	- -
8	31,541	- - -	150,303	- -
9	33,281	- - -	184,382	- -
1790	- - - -	- - -	- - - -	- -
1	- - - -	- - -	- - - -	- -
2	- - - -	- - -	- - - -	- -

* The "Standard" means the price paid the miner for the copper in the ore, from which are deducted the expences of bringing it to a state of purity. The sum deducted for these expences since 1805, has been fifty-five shillings for every ton of ore.

† The produce of this and some succeeding years cannot be ascertained.

Years.	Tons of Ore.	Tons of Copper.	£	Standard.
1793	- - - -	- - -	- - - -	- -
4	42,816	- - -	320,875	- -
5	43,589	- - -	326,189	- -
6	43,313	4,950	356,564	- -
7	47,909	5,210	377,838	- -
8	51,358	5,600	422,633	- -
9	51,273	4,923	469,664	121
1800	55,981	5,187	550,925	133
1	56,611	5,267	476,313	117
2	53,937	5,228	445,094	111
3	60,566	5,616	533,910	122
4	64,637	5,374	570,840	136
5	78,452	6,234	862,410	170
6	79,269	6,863	730,845	138
7	71,694	6,716	609,002	120
8	67,867	6,795	495,303	100
9	76,245	6,821	770,028	144
1810	66,048	5,682	569,981	132
1*	66,499	5,948	563,742	126
2	75,510	7,248	608,065	113
3	86,713	8,166	685,572	113
4	87,482	7,936	766,825	128
5	79,984	6,607	582,108	121
6	83,058	7,045	541,737	109
7	75,816	6,608	422,426	96
8	80,525	6,714	587,977	121
9	93,234	7,214	728,032	136
1820	92,672	7,364	620,347	119
1	98,803	8,163	628,832	111
1822	106,723	9,331	676,285	104

* The accounts of this and the following years are made up to the 30th June in each year.

Quantity of Copper produced in Great Britain and Ireland, in the Year ending the 30th June, 1818.

	Tons.
Cornwall — —	6714
Devonshire — —	438
Staffordshire — —	200
Anglesea — —	633
Other parts of North Wales	90
Ireland — —	120
	8195

Purchased by the following Companies.

	Tons.
Williams, Grenfells, & Co.	1380
Vivian and Sons, and Patten and Co.	1438
Daniell & Co. — —	953
Birmingham Co. —	852
Crown Co. — —	810
Rose Co. — —	692
British Co. — —	394
Freeman and Co. —	374
Cornish Co. — —	301
Mines Royal Co. —	198
English Co. — —	140
Brass Wire Co. — —	93
Anglesea Co. (smelted)	570
	8195

Quantity of Copper produced in Great Britain and Ireland, in the Year ending the 30th June, 1819.

	Tons.
Cornwall — —	7214
Devonshire — —	433
Staffordshire — —	180
Anglesea — —	564
Other parts of North Wales	60
Ireland — —	116
	8567

Purchased by the following Companies.

	Tons.
Vivian and Sons, and Patten and Co.	1812
Williams, Grenfells, & Co.	1146
Birmingham Co. —	934
Rose Co. — —	867
Daniell & Co. — —	834
Crown Co. — —	776
Freeman and Co. —	407
Brass Wire Co. — —	331
English Co. — —	268
Cornish Co. — —	235
British Co. — —	219
Mines Royal Co. —	170
Spitty Bank Co. —	4
Anglesea Co. (smelted)	564
	8567

Quantity of Copper produced in Great Britain and Ireland, in the Year ending the 30th June, 1820.

	Tons.
Cornwall — —	7364
Devonshire — —	417
Somersetshire — —	3
Staffordshire — —	236
Anglesea — —	561
Other parts of North Wales	40
Ireland — —	174
	8795

Purchased by the following Companies.

	Tons.
Vivian and Sons —	1553
Williams, Grenfells, & Co.	1308
Daniell & Co. — —	1236
Rose Co. — —	982
Crown Co. — —	828
Birmingham Co. —	765
Freeman & Co. —	486
English Co. — —	420
Patten & Co. — —	331
British Co. — —	182
Brass Wire Co. —	84
Mines Royal Co. —	59
Anglesea Co. (smelted)	561
	8795

Quantity of Copper produced in Great Britain and Ireland, in the Year ending the 30th June, 1821.

	Tons.
Cornwall — —	8163
Devonshire — —	483
Somersetshire — —	28
Staffordshire — —	110
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5. *Copper.* Black Copper Ore. Velvet Copper Ore. Copper Glance. Black Oxide of Copper. White Copper. Tile Copper. Copper Green. Iron Shot Copper Green. Copper Mica. Martial arseniate of Copper.

6. *Iron.* Hepatic or Liver Pyrites.

7. *Manganese.* Black Manganese Ore. Wad. Sulphuret and Phosphate of Manganese.

8. *Titanium.* Iserine. Nigrine.

9. *Lead.* Blue Lead Ore. Native Minium. Corneous Lead Ore. Brown Phosphate of Lead.

10. *Zinc.* Red Zinc Ore. Electric Calamine.
11. *Bismuth.* Cupriferous Bismuth Ore. Bismuth Ochre. Bismuth Glance.
12. *Tellurium.* Native Tellurium. Yellow and Black Tellurium Ore.
13. *Antimony.* White Antimony Ore. Antimony Ochre.
14. *Cobalt.* Cobalt Pyrites. Cobalt Ochre.
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5. *Azure-stone.* Azurite. Blue-spar.
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7. *Lithomarga.* Green earth. Pimelite. Mountain soap. Yellow earth. Cimolite. Kollyrite.
8. *Talc.* Axestone. Potstone. Nacrite. Picrolite.
9. *Hornblende.* Anthrophyllite.
10. *Chrysolite.* Sahlite. Coccolite.
11. *Dolomite.* Miemite. Gurhofite.
12. *Limestone.* Tabular spar. Aphrite. Agaric mineral.
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15. *Hallite.* Cryolite.

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Variegated Copper,—Azure Copper,—Phosphate of Iron,—Crystallized Galena,—Sulphate of Lead,—Crystallized Blende.

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